DOCUMENT RESUME

ED 428 968 SE 062 364

TITLE	Fun with Physics: Real-Life Problem Solving for Grades K-3.
INSTITUTION	Ohio State Univ., Columbus. Vocational Instructional Materials Lab.
SPONS AGENCY	Department of Labor, Washington, DC.
PUB DATE	1998-00-00
NOTE	382p.; Colored paper may not reproduce clearly.
AVAILABLE FROM	Center on Education and Training for Employment, Publications, 1900 Kenny Road, Columbus, OH 43210-1090; Tel: 800-848-4815 (Toll Free).
PUB TYPE	Guides - Classroom - Teacher (052)
EDRS PRICE	MF01/PC16 Plus Postage.
DESCRIPTORS	*Hands on Science; Inquiry; Knowledge Base for Teaching; Learning Activities; Learning Strategies; *Physics; Primary Education; *Problem Solving; Science Curriculum; Science Education; *Science Process Skills; Teaching Guides

ABSTRACT

This teachers' guide presents scientific background succinctly and in an easy to read format for teachers of K-3 students. The learning theory is explained and modeled and activities reflect a hands-on, minds-on philosophy. The exercises were tested in non-science classrooms and learning activities incorporate inquiry-based learning, process skill development, and problem-solving skill development. Topics for activities include simple machines, electricity, heat, and liquids. Appendices contain references, resources, basic scientific principles, material related to gender equity, problem solving activities, and selected science proficiency outcomes. (DDR)

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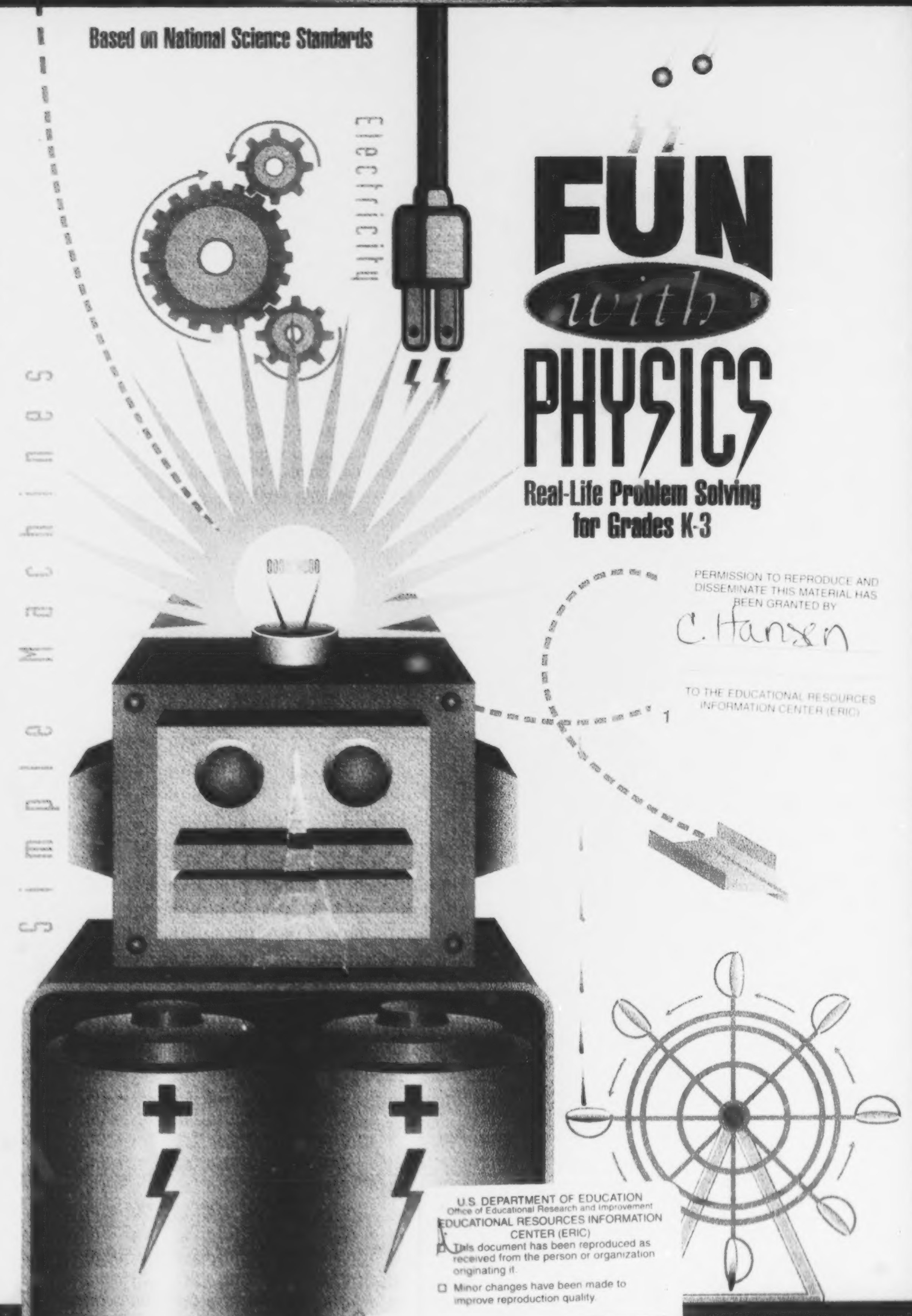
ED 428 968

Based on National Science Standards

FUN with PHYSICS

Real-Life Problem Solving for Grades K-3



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FUN with PHYSICS

Real-Life Problem Solving for Grades K-3

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Note to Non-Science Teachers and Other Professionals

Science is a topic that is sometimes under-emphasized—especially in elementary-level classrooms. Since certification to teach elementary school is not subject-area specific, K-6 teachers can feel unprepared to lead lessons in a content-rich subject like science. However, the information in this book is designed to empower *anyone*—even non-science teachers—to teach science.

In *Fun with Physics: Real-Life Problem Solving for Grades K-3*, scientific background is presented succinctly and in an easy-to-read format. Even the learning theory behind the practical exercises is explained and modeled for the reader. In addition, the book's activities are hands-on and "minds-on," drawing students into their own learning. And the exercises have been tested successfully in non-science classrooms, demonstrating that you, the teacher, do not have to be a physics expert. You can learn along with the students and relieve yourself of the pressure to know all the answers. If mistakes are made in completing the activities, so much the better! Learning has still taken place because trial-and-error is a very effective teaching method, not to mention problem-solving process. Thus, anyone—from veteran science teacher to inexperienced professional—can feel comfortable using any section of this resource.

So relax and let the learning begin! Ask questions, predict, and observe with your students. We believe that both you and your students will have fun—and become scientific thinkers and problem solvers in the process!

Scientifically yours,

Authors and pilot teachers, *Fun with Physics*

P.S. If, after reading through the activities, you are confused or concerned, we encourage you to seek help from someone in your school or your district. Many people would be delighted to support your efforts, but a science teacher may be the most helpful. If you cannot find assistance within your district, feel free to contact one of the book's contributors.

PREFACE

Project Overview

Fun with Physics: Real-Life Problem Solving for Grades K-3 was developed with funding from an Ohio School-to-Work Systems Building Grant. The goal was to develop resources for teachers and trainers to use in helping students improve their scientific thinking and problem-solving skills in real-life situations.

This book, and its companion volume, *Fun with Physics: Real-Life Problem Solving for Grades 4-8*, were co-written and piloted with a diverse group of teachers and teacher trainers. In addition, fifty K-8 teachers provided practical input for the books through a week-long Applied Technology Institute. During the institute, they learned to teach problem solving with physics and made worksite visits to learn how academics are used at work.

Both books are distributed by The Ohio State University's Vocational Instructional Materials Laboratory (VIML), a division of the College of Education's Center on Education and Training for Employment. Similar books for grades 9-12 and adults, which support ACT's Work Keys™ System, also have been developed and are distributed by the VIML. The sales office can be reached by telephone at 800/848-4815 or fax at 614/292-1260.

In-Service Training

The VIML provides coaching and training that will prepare teachers and trainers to effectively use the *Fun with Physics* books and other VIML publications. Workshops in problem solving with physics and math for grades 9-12 and adults working in industry are also available. For further information about these services, contact the VIML directly at 800/848-4815 or 614/292-5001.

ACKNOWLEDGMENTS

The project staff extend sincere thanks to the many people who committed their time and talents to create this useful resource for teachers and other professionals who want to provide opportunities for students to solve real-life physics problems.

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ABOUT THIS BOOK

Purpose

Many teachers want to prepare students to be effective problem solvers, but they don't have the time or the expertise to design the necessary learning strategies. *Fun with Physics: Real-Life Problem Solving* was developed as a practical guide and resource for these teachers. Its easy-to-read format and tested learning activities can be adopted by professionals outside academic settings, as well.

The following parameters guided the authors as they created *Fun with Physics*:

- *Fun with Physics* was written for **non-science teachers**. You can make full use of this book without any formal training in physics or other science areas. Still, even formally trained physics teachers will find value in this book's practical focus on applications to real-life situations.
- *Fun with Physics* gives teachers a **brief background** about the key scientific principles involved in the learning activities. It does not provide in-depth information about those principles or a comprehensive list of the scientific principles involved in solving real-life problems. Such a list does not exist. However, a *brief* list of basic scientific principles was compiled by *Fun with Physics* pilot teachers. See Appendix C on pp. 315-327.
- The skills addressed in *Fun with Physics* are intended for **all students**—not just those who plan to study in technical areas, because almost everyone encounters physics-related problems that demand to be solved. A few such challenges are fixing toys and bicycles; operating copy machines, computers, and VCRs; and repairing toilets.

- *Fun with Physics* **supports what teachers are already doing** by offering ideas and materials for achieving their current goals and objectives. It is not a new program or a new curriculum. Rather, it is a resource that complements existing instructional efforts.
- Because *Fun with Physics* is not meant to be a complete curriculum, it **supplements the established curriculum** by giving teachers a wide variety of learning activities from which to choose, as needs arise.
- *Fun with Physics* was designed to help students become more effective problem solvers, which involves process skills that have been identified in **national standards** and are measured by state proficiency tests. Therefore, the National Science Education Standards and the Benchmarks for Science Literacy were considered in the book's development.
- Each learning activity in *Fun with Physics* notes the specific **Ohio Science Proficiency Outcomes** that it addresses. Proficiency Outcomes are listed in Appendix F, pp. 353-354.
- *Fun with Physics'* activities allow students to solve real-life problems that involve physics principles associated with simple **machines, electricity, heat, and liquids**.

Structure

Fun with Physics includes a wide variety of information that will help you, the teacher, provide students with highly effective instructional experiences in scientific thinking and problem solving. In the **Learning Concepts and Strategies** section, you will find information and insights about relevant learning theories and their practical applications, such as **inquiry-based learning, process skill development,** and **various instructional strategies**.

The information provided in the section titled **"How to Use This Book"** will help you figure out how to start using the ideas found in *Fun with Physics*, as well as **assess** your efforts. The **Learning Activities** section is divided into physics categories, i.e., **simple machines, electricity, heat, and liquids**. An index of problems is included for each category.

The final section of the book contains a variety of **support materials** to help you use the concepts and activities provided in this book, as well as to develop and enhance your own learning activities. These appendices include:

- Basic scientific principles (Appendix C)
- Resources for teachers (Appendix B)
- Resources for students (Appendix B)
- Proficiency outcomes (Appendix F)
- Problem solving (Appendix E)
- Gender equity (Appendix D)
- Matrix of proficiency outcomes and process skills (Appendix G)

Notes

FUN WITH PHYSICS:

Real-Life Problem Solving for Grades K-3

Learning Concepts & Strategies

This section describes the learning concepts that undergird the real-life learning activities developed for this book. It also outlines teaching strategies for building a learning environment that develops scientific thinking and problem solving.

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INQUIRY-BASED LEARNING

What Do We Mean By "Inquiry-Based Learning?"

Inquiry-based learning puts the student at the center of the learning process. The student gains an understanding of the material through active participation rather than from passive activities like listening and taking notes. When using an inquiry-based learning format, **teachers provide students with opportunities to ask scientific questions, then answer those questions for themselves through investigation**.[1] When structuring learning activities of this type, teachers should consider these inquiry-based instructional characteristics:[2]

- Starts with questions
- Engages students actively
- Concentrates on collection and use of evidence
- Requires clear expression (e.g., written and verbal communication)
- Uses a team approach
- Does not separate knowing from finding out
- Welcomes curiosity and rewards creativity
- De-emphasizes memorizing technical vocabulary

Why is Inquiry-Based Learning Important to Scientific Problem Solving?

Solving science problems involves inquiry—predicting, testing, observing, and concluding. So, it makes sense to help students explore concepts through inquiry as part of teaching problem solving. Since inquiry-based learning helps students to gain an understanding of the material **through active participation**, they are more likely to remember what they learn. Additionally, studies show that passive learning is much less effective than active learning.

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[1] *Science With Reason* (1995) p. 7

[2] *Benchmarks for Science Literacy* (1993) professional development CD-ROM.

Even more important than such studies is wisdom derived from personal experience. Most of us have experienced first hand both passive and active learning. Wasn't it much easier to both comprehend and retain information that you *experienced* in a lab setting than information you *heard* during a lecture?

An Inquiry-Based Learning Model

Many teachers have used the **Five Es of Instruction**, an inquiry-based learning model, with great success. The Five Es, which is an expansion of the learning cycle, can be used as a *format for structuring lessons* that allows people to learn through an inquiry-based process. The components of the Five Es are listed and described below.

Engagement *How will you introduce the topic and get students interested?* What "hook" will you use to motivate students to learn more about the topic? How will you promote excitement? Engagement usually involves students in a thought-provoking or discrepant event. Demonstrations followed by an entire-class or small-group discussion are often used. In science education, the engagement step usually helps students gain insight into their preconceived ideas about a given concept. (Note: This step is optional. Sometimes, the exploration activities outlined in the next paragraph are sufficient "hooks" to engage students.)

Exploration	*What hands-on activities (e.g., investigations, discussions, individual and/or cooperative group activities) will guide students to make observations, identify patterns, and collect data?* Please note that during exploration, students are **not** given explanations about what to expect, why things happened as they did, or new vocabulary.
Explanation	*In this stage, the teacher's job is to help students draw conclusions and form new ideas from their observations and the patterns that surfaced during exploration.* Traditional instructional strategies (e.g., demonstrations, short lectures, lecture-discussions, textbook assignments, group reports, video tapes, and library research) may be included at this time.
Evaluation	*How will you confirm that students understand the concepts and processes delivered during their inquiry-based learning experience?* Both traditional testing methods (e.g., quizzes, unit tests, essays) and practical assessments (e.g., spontaneous oral reports, teacher observation, and reflective journal entries) can be used.
Extension	*What possibilities exist for building upon what was learned in this activity?* In this segment of the model, teachers help students use what they learned to solve new problems.

Here's how one teacher used the Five Es format to structure a physics-related learning activity. Feel free to use it to create your own scientific learning exercise!

Engagement

The teacher wanted to introduce the principles of electricity to her students. Beginning with a **discrepant event**, she asked students to predict what would happen when she touched a pickle with 2 wires that were attached to a battery. After the students offered a wide range of predictions, she poked a wire into each end of the pickle and it lit up! She then explained to the students that they would have the opportunity to determine why that happened.

Exploration

Immediately following the introduction, the teacher provided each student with a zip-type sandwich bag containing a battery, 2 coated copper wires, a flashlight bulb, a bulb holder, and masking tape. Instructions were not included and she did not give any verbally. She simply challenged them to make the bulb light up. As students worked, the teacher walked around the room to observe what they were doing, to give hints to students who were "stuck," and to provide input and direction by asking open-ended questions. She did not give any answers, but she encouraged students to share ideas with each other. After the students tried several methods for lighting the bulb, the teacher distributed a worksheet titled "How many ways can you make a bulb light?" Students were asked to draw diagrams in two columns: "Ways the Bulb Lit" and "Ways the Bulb Did Not Light." [3]

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[3] Learning activity from the Electricity book developed by TOPS Learning Systems. See description in Appendix B, Guides for Educators section.

The next day, the class reviewed the worksheet. Then the teacher gave each student a zip-type sandwich bag containing 3 batteries, 4 coated copper wires, 2 flashlight bulbs, 2 bulb holders, and masking tape. She challenged them to learn everything they could by connecting the materials. Again, no further instructions were given. As she circulated among the students, most of them highly motivated, she asked questions such as, "What would happen if you connected two or more bulbs?" and encouraged students to learn from each other with comments like, "Maybe Andrea can explain to you how she connected her bulbs." For homework, students completed a worksheet[4] that required them to predict which battery-wire-bulb configurations would make a bulb light and which would not.

Explanation

Once the students had been given plenty of time for exploration, the teacher facilitated a class discussion during which they shared what they learned from the experiences. The teacher asked questions like:

- "To light the bulb, what specific places on the battery must be touched?"
- "How could you get your bulb to shine brightly?"
- "How could you attach your bulbs so that they all light up?" and "Were they all equally bright?"
- "When two or more bulbs were attached, how could you get them to shine the brightest?"
- "What other observations did you make?"
- "What conclusions can you draw from your observations?

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[4] Ibid.

"Suppose you had a string of Christmas tree lights and a bulb burned out. What would happen? Why? What would happen if appliances in your home were arranged like Christmas tree lights?"

Next the teacher guided class discussion to help students make generalizations about electricity, including the following:

- Metal ends of batteries, wires, and bulbs need to be joined together in order for the bulb to light. Students labeled this a *circuit*.
- Bulbs attached beside each other (students labeled these *series circuits*) were brighter than those attached in a row (students labeled these *parallel circuits*).
- The more batteries in a circuit, the *brighter* the bulbs glow.
- The more bulbs in a circuit, the *dimmer* the bulbs glow.

Finally, the class brainstormed how principles of electrical circuitry are used in their homes, school, and community.

Evaluation

The teacher checked individual students' understanding of the principles of electricity by giving a quiz. Students were asked to reconstruct six electrical circuits from diagrams and explain how each circuit worked. In addition, the teacher checked students' journal entries to check for their understanding of the basic principles related to electricity.

Extension

Once the students demonstrated a basic understanding of primary electrical principles, they were assigned new tasks[5] that required them to solve additional problems and apply what they had learned to real-life situations. Activities included building an electrical game board and designing a flashlight. In addition, teams of students constructed a building that lights from empty food boxes and the electrical supplies they had used during the unit. The class then put all the buildings together to create a "city of lights." This type of inquiry-based "teaching," conducted **after** students explored the concepts for themselves, helped students absorb the concepts and master practical use of the knowledge gained.

What is the Teacher's Role in Inquiry-Based Learning?

Since inquiry-based learning is student centered, the teacher becomes a **facilitator** rather than a "bestower of knowledge." Facilitator is a new role for many teachers. The information presented in this section is designed to help teachers transition more smoothly into this role. Facilitating inquiry-based learning requires:

- Determining the content that will be studied
- Organizing exploratory experiences for students
- Facilitating student questioning

In short, an inquiry-based teacher provides a framework for **collecting information** and **making generalizations**.

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[5] The teacher found ideas for extension activities in books written for both educators and students. For examples, see Appendix B, Resource section.

Specifically, teachers use the Five Es of Instruction to structure a learning activity. First, the facilitator provides a motivating activity, then explains what is expected in the exploration activity—including safety precautions. Next the teacher steps back and allows students to discover answers for themselves. Once discovery has occurred, the facilitator helps students synthesize what they have learned, label it, and apply that understanding to other situations. In this way, **teachers *facilitate* the learning process rather than control or direct it**.

In inquiry-based learning, the facilitator also functions as a **resource person** for students. For example, a resource person assists the class by encouraging *them* to locate answers to their questions rather than *giving* the answers. A resource person gives only information that is absolutely necessary and lets students discover the rest for themselves.

To be successful in the facilitator and resource person roles, teachers may need to develop skills in some different instructional methods, including those outlined in the following table.

Facilitator's Role in Inquiry-Based Learning

Instructional Method	***Explanation/Examples***
Put students in the center of the learning process.	Learn facilitation skills and become proficient in them, so that you become an expert at drawing students into the center of their own learning.
Include process skills in developing the learning activity so that students can learn and practice them.	See the next subsection, titled "Process Skill Development," for a complete description of process skills, as well as sample learning activities.
Lead discussions.	Guide students into discussions by **making observations** and **asking questions**. For example, all students used the same materials in an experiment, but some bulbs are dimmer than others. Ask the class, "What could some students do differently to make their bulbs brighter?" Discussions are excellent tools for evaluating student learning, discovering extension opportunities, helping students clarify ideas and much more.
Use discussions to stimulate logic, reasoning and communication skills. *Embrace the concept of not knowing the answers to student questions.*	For example, present an exercise to the class. After allowing students time to process the information, ask a few to share their **hypotheses** and **make predictions** (or guesses), being careful to facilitate the discussion in a way that helps students share the logic and reasoning behind their ideas. Then encourage all students to **test** these and their own hypotheses and predictions while completing the exercise. Upon completion, guide the same students in a discussing their test results with the class. In this way, the facilitator is **encouraging students to synthesize their understanding and share that knowledge with peers**. Some questions teachers might use to encourage students in this way include:[6] ? Draw out the student's reasoning with, "Are you saying that...?"

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[6] Questions adapted from Matthew Lipman's work, which is cited in *Science With Reason*, pp. 36-37.

	? Help students provide validity to their statements with, "Why do you think...?" ? Help students identify alternatives with, "Couldn't it be right that...?" ? Help students provide supportive evidence with, "How do you know that ...?" ? Lead students to finding supportive evidence with, "How might we find out whether...?"
Embrace the concept of not knowing the answers to student questions.	**Get comfortable** with sentences like, "I don't know." and "That's a new one on me!" Equally important, always follow-up sentences like those cited with questions that lead students to finding their own answers, e.g., "What could you do to find out?" In this way, you are modeling exactly the behavior you are instructing students to adopt. Additional information concerning questioning can be found in the rest of this table and the following subsection, "Inquiry-Based Learning: Questions Teachers Might Ask."
Create an instructional environment that provides a sturdy foundation for inquiry-based learning.	For inquiry-based learning to achieve the desired results, you should **build a "safe" environment for participation**. For example, when questioning, your *tone of voice* must convey a sincere desire to know the answer. In addition, your *behavior* must consistently show students that a wrong answer is okay. For example, avoid right or wrong labels; redirect the student instead, e.g., "Is there another method/alternative?" A sturdy foundation also requires the consistent use of positive feedback, like "Sally, you've really been persistent when doing this exercise. Good job! Why don't you take 5-10 minutes to observe some of the other students' work and get some new ideas?" Positive feedback also encourages enthusiasm.

Replace "bestowing knowledge" with asking questions.

This is one of the most difficult facilitation skills to develop. Mastering it requires significant planning and commitment. Many teachers find the following strategies helpful in becoming an expert questioner.

- **Prepare start-up questions** in advance, and make sure they cover the key points of the discussion.
- **Ask open-ended questions**—anything that *cannot* be answered with "yes" or "no!"
- **Prepare questions that require students to think critically** in order to explain their observations and draw conclusions. Let's use the light bulb exercise as an example of critical thinking questions. You could ask students to:
  - Explain what they observed with, "Why is there a limit to the number of bulbs that will light up with one battery?"
  - Synthesize what they learned with, "What can you generalize about all circuits?"
  - Develop predictions based on what they understand to be true with, "What would you predict will happen when more batteries are used?"
  - Apply what they learned to other situations with, "When planning electrical circuitry for a new building, what do engineers need to consider?"
- When appropriate, **answer students' questions with other questions**, and/or **direct them to other students** for answers.

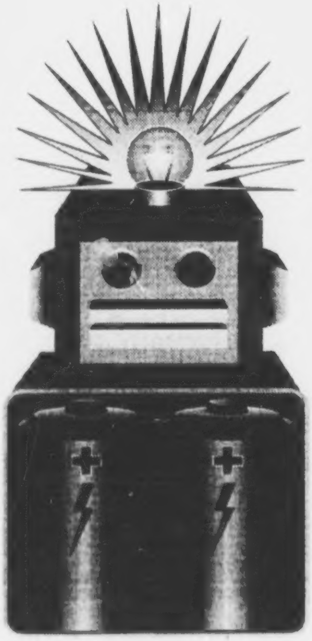
- After asking individual or groups of students a question, **allow 5-10 seconds of silence** (which is sometimes called wait time) before giving a prompt or calling on someone else. Wait time encourages participation from students who lack confidence and who prefer to mentally check their answers.
- **Ask questions without bias.** Demonstrate gender equity by posing the *same number of questions* to both male and female students, asking *challenging questions* of both male and female students, and following every student's answer to one question with a *second, more difficult question.* Refer to Appendix D, "Gender Equity: What Can I Do?" on pp. 329 for additional ideas.

In addition, please see the beginning "database" of questions on the following page. It contains lists of questions that teachers might ask students during science-related learning experiences.

Inquiry-Based Learning: Questions Teachers Might Ask

Questions that teachers can ask students to encourage them to explore and synthesize the concepts they're studying are virtually unlimited. The following sample of open-ended questions can be particularly useful in **exploring scientific principles**.

- "What would happen if ......?" For example, "What would happen if you added more batteries?"
- "What makes you think that?"
- "What else could you try, in order to find out?"
- "What would you predict?"
- "How do you know?"
- "What isn't being considered?"
- "What are the facts and limitations?"
- "What is (or can be) reasonably inferred?"
- "What potential outcomes and/or precautions should be considered?"
- "What do you need to consider in order to determine ________?"



Teachers can also ask specific, open-ended questions that guide students in **investigating systems** and solving problems related to those systems. Prompts from the following list [7] could guide instruction on practically any system.

1. "When this system is working, what does it do?"
2. "Must this system receive input in order to function?"
3. "What, if any, output does this system produce?"
4. "Identify at least four parts of this system. Describe what each part does, and tell how each part contributes to the system as a whole."

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[7] *Benchmarks for Science Literacy* (1993) professional development CD-ROM.

5. "Choose an interesting part of the system and list at least four words or phrases that describe that part. Which, if any, of those words or phrases also describe the whole system?"
6. "Could any of the parts of this system be made of different material without affecting how the system works? Explain."
7. "Can any one part of the system do what the whole system does? Explain."
8. "Can you take a part from another system of the same kind and use it to replace a part in this system? If you do so, will this system work the way it does now?"
9. Identify at least two parts of this system that must interact if the system is to function. Describe how these parts interact. Could the parts of this system be arranged differently and the system still function?"
10. "What is the boundary of this system?"
11. "Can you identify any subsystems within the whole system? If so, describe one."
12. "Does this system require symmetry between any of its parts? If so, describe the symmetry."
13. "Describe how the functioning of this system would change if one of the parts wears out."
14. "If this system stops working, how would you go about fixing it?"
15. "Give an example of how this system might respond to a stimulus from outside itself." or "Give an example of how this system might respond to a stimulus from the environment outside the system."
16. "In what way is it useful to think of this item as a system?"
17. "Could someone develop a computer simulation of this system? Justify your answer."

Practical Application: Students can study systems by analyzing **a toy as a system**. Sample questions that could be used to facilitate inquiry-based learning in this situation are listed below.

- "How does this part help the toy work?"
- "How did you figure out what this part does?"
- "If the part does not help the toy work, is there some other reason that it is important to the toy?"
- "Does this part affect other parts of the toy in any way?"
- "If you put the parts of this toy together in a different way, would it still work like it does now? Explain your answer. Use drawings, if you wish."
- "Could you take away any part of this toy without changing the way the toy works? If so, which part(s)?"
- "Let's take the information you learned about systems from this toy and see how it applies to things around the school. Can you identify three parts of our school's system?"
- "How does each part affect the other two?"
- "If you took one of the three parts away, would it affect our school's system? Please explain."

Practical Application: Here are some questions that could be asked of students who are studying **the bicycle as a system**.

- "Identify at least six parts of the bicycle. If you don't know the name of a part, make up a name. Explain the function of each part."
- "The seat is one part of the bicycle. Use three words or phrases to describe the seat. Do any of these words or phrases also describe the whole bicycle?"
- "Could any part of this bicycle be made of a different material and still help the bicycle carry out its function?"
- "Can any one part of the bicycle carry out the job of the whole bicycle? Explain your answer."
- "What parts of the bicycle must work together if you want to ride around a corner?"
- "Can you take a part from another bicycle and use it to replace a part in this bicycle and still have the bicycle carry out its function?"
- "Could some parts of the bicycle be arranged differently and the system still carry out its function? Explain your answer."
- "Can you identify any subsystems within the whole bicycle system? If so, describe one subsystem."
- "Does the bicycle require symmetry between any of its parts? If so, describe the symmetry."
- "What will happen to the bicycle if one part, such as a spoke, breaks? What if all the spokes break?"
- "Is it useful to think of a bicycle as a system? Justify your answer."
- "Now think about our cafeteria system for a minute. In what ways does it function like the bike system?"

Inquiry-Based Learning in the Real World: A Teacher's Reflections

Dear *Fun with Physics* User,

Students arrive in our classrooms with a variety of perspectives on science—depending on their past experience. Our job is to create an environment in which each student can learn the objectives and skills set by us and the curriculum. Inquiry-based learning is one of the best ways I've found to create such an environment. However, success in this endeavor requires experience, knowledge, personal commitment, and organization. Most important, successful teaching through inquiry requires a student-centered mind-set that is obvious at all times. This book can help you gain knowledge and experience; commitment is an individual task. So, I'll share some key points I've learned about organization and the student-centered mind-set.

Organization and Focus. I design textbook reading and note taking into most learning activities. My 6th-graders read background information as preparation for the lab portion of the exercise. They must take notes—one note per paragraph. The reading familiarizes students with the general topic; note taking helps with retention and keeps them focused.

Organization and focus can be achieved in the lab experience, too. I start by clearly defining the objectives and skills to be targeted, then wrap them into the scientific process to create a learning activity that provides a feeling of discovery for my students. My lab exercises usually begin with a question developed by either the students or me. Research follows; it can be as simple as the verbal description of a ping pong ball or a written report. Next, students write a hypothesis—a guessed answer to the lab question. Then they complete the experiment part of the lab, focusing on answering the question. Students are given supplies and/or data with which they can work out an answer. To keep them focused on the question, I write it on the board or have students write it in the notes section of their folders. My labs end with clean-up and sharing what we learned through verbal, dramatic or similar presentation. Consistent with the scientific process, students answer the lab question while sharing lab results. Often results lead to more questions, which can be investigated in future lab experiences—either in the classroom or at home. My most successful labs have been those that prompted students to involve their families in an extension of the learning at home.

Student-Centered Retention. I frequently tell my students,"Knowing the meaning of a word is power." For this reason, the students and I create vocabulary words from both the textbook reading and the lab experiences described above,and a student lists them on the board. The class defines the words based on these learning experiences. Then they verify the definitions with a dictionary. Finally,the words and definitions are stored in the vocabulary section of students' folders. These can be used later in an assignment; however, most frequently the words are seen again in future reading or in a test question only.

Potential Problem with Student-Centered Methods. Inquiry-based classroom experiences allow students to take significant responsibility for their learning. Teachers must be cautious, however, about assuming that because the student completes the experience, learning has occurred. Ways I have found to avoid this potential problem are to: (1) keep students focused on the learning procedure, and (2) stay organized. The methods I described in this note really help!

I hope that sharing some of my experiences with inquiry-based learning encourages you to try it yourself. The time and energy required to gain knowledge and experience in this method, as well as to maintain focus and organization, pays huge dividends in successful learning outcomes.

Wishing you much success,

Patricia Bosh
Mifflin International Middle School Teacher and *Fun with Physics* Author

Notes

PROCESS SKILL DEVELOPMENT

What Do We Mean By "Process Skill Development?"

Learning subject matter **content** (e.g., facts, theory) has always been a primary function of instruction. Such learning is especially important in science, because students must understand basic scientific principles in order to become proficient in competencies identified by science educators. Similarly, to be successful on the job, workers must understand the scientific principles that underlie systems they work with.

However, learning such content is not enough. People also must be able to *apply* their content knowledge in problem-solving situations. Developing **process skills** meets this need. When paired with scientific knowledge, process skills allow students to **participate** in the *scientific process.*

The Process Skills Checklist on the next page defines the process skills generally used in science education. You may wish to use it to identify the process skills you are currently helping students develop and practice, and other skills you want to work on. (In addition, see the information concerning assessment, on pp. 45-51, where you will find a sample tool for assessing process skills.)

Why Are Process Skills Important to Instruction?

Process skills, when coupled with subject knowledge, lay the foundation for people to successfully solve problems in real-word situations. Traditional teaching curricula and methods already successfully impart the necessary **facts**, **data**, and **theory**. However, most do not include learning activities aimed at developing **process skills**. Consequently, teachers of all levels need to add process skill development to their science instruction plans.

The benefits of process skill development go beyond creating better skilled problem-solvers, however. When learning activities are geared toward helping students practice process skills, the learning becomes more **active**. And active students learn more than those who listen to lectures or observe demonstrations.

Process Skills Self-Check

In the first column, check the process skills that you currently use in instruction. In the second column, check those skills you'd like to add or expand upon. Use the resulting information as you choose *Fun with Physics* activities to use in your classroom.

I Provide	I Want to Do More	
○	○	**Building models:** Constructing a physical or mental representation to explain an idea, object, or event.
○	○	**Categorizing or classifying:** Grouping or ordering objects or events according to an established scheme, which is based on observations.
○	○	**Communicating:** Giving or exchanging information (e.g., insights, explanations, results of observations or inferences, measurement) to others verbally, pictorially, or in writing.
○	○	**Comparing:** Relating one thing to another so that similarities and differences can be identified.
○	○	**Controlling variables:** Manipulating one factor that may affect the outcome of an event while other factors are held constant.
○	○	**Experimenting:** Use observations to collect and analyze data in order to draw conclusions and solve a problem.
○	○	**Hypothesizing:** Stating a problem to be solved as a question that can be tested by an experiment.

I Provide	I Want to Do More	
○	○	**Inferring:** Developing ideas based on observations and suggesting explanations, reasons, or causes for observed events.
○	○	**Interpreting data:** Using the data collected during scientific investigations to answer questions about a scientific investigation.
○	○	**Measuring:** Comparing objects to arbitrary units that may or may not be standardized.
○	○	**Observing:** Using one or more of the senses to gather information. May include the use of equipment.
○	○	**Ordering:** Using observed characteristics to organize objects or systems in a sequence.
○	○	**Predicting:** Forming an idea of an expected result. Based on prior observations and inferences.
○	○	**Recognizing relationships:** Interpreting interactions between different components of a system.
○	○	**Recording:** Creating a written record of observations made during experimentation, including diagrams and/or graphs.

Notes ______________________________

How Can Teachers Help Students Develop and Practice Process Skills?

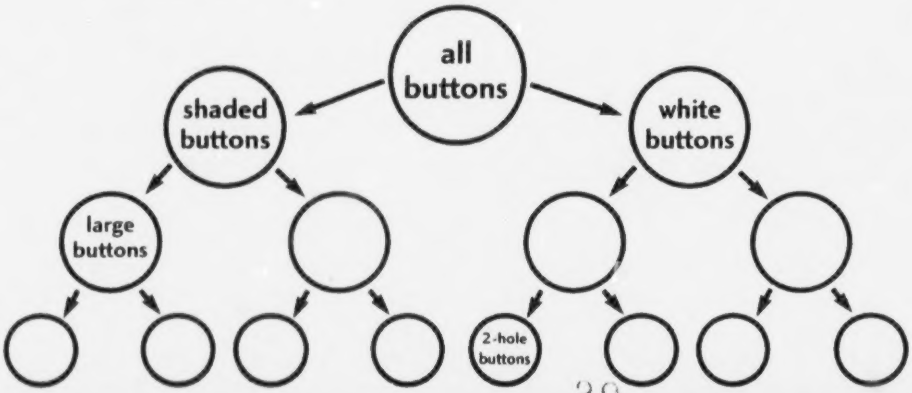
Students learn process skills most effectively through **practice**. Frequently, these skills can be integrated with instruction about scientific principles. The learning activities provided in this book allow students to practice a wide variety of process skills while learning basic scientific principles. (The first page of each learning activity outlines the process skills targeted. In addition, a chart that identifies the process skills included in each learning activity is located in Appendix G, pp. 360-364.)

In addition, there are probably situations that are more suited to **direct instruction** of process skills. For example, very young students have difficulty grasping the technical detail and scientific principles necessary to either perform or learn from experiments. However, even very young students can discern differences in shape, color, form, texture, size, and similar attributes—allowing them to successfully complete a variety of *classification* exercises. Isolated process skill instruction, therefore, is both effective and important in teaching younger students.

Teaching process skills in isolation provides students with the foundation skills needed for future scientific problem solving. Let's use the process skill of classification for another practical example of direct instruction of such skills. Scientists put the objects they study into categories in order to understand similarities and differences—the classification process. Similarly, the ability to organize (e.g., information, inventory, budget data—even people) is important to success at work. Students can develop these important organization/classification skills from activities that help them to sort objects with the same or different characteristics. Some sample classification activities follow.

Classification Activity 1: Button Sort Procedure

1. Organize students into groups of 2-4.
2. Give each group a varied assortment of buttons.
3. Challenge them to develop categories and sort the buttons according to their categories.
4. To help them recognize the characteristics of buttons that can affect classification, you might ask questions like:
   - "How many buttons are there all together?"
   - "How many shaded buttons are there?"
   - "How many white buttons are there?"
   - "How many buttons have four holes?"
   - "How many white buttons have four holes?"
   - "How many shaded buttons have two holes?"
   - "How many shaded buttons have four holes?"
   - "How many buttons have two holes?"
   - "How many large buttons have two holes?"
5. Have students develop a chart that reflects their findings. Many younger students may need a partially completed chart like the one below. (Note: Depending upon the skill levels of the students, you may want to complete the chart individually, in teams, or as an entire class.)



Classification Activity 2: Observable Characteristics Procedure

1. Provide groups of 2-4 students with items they can use to practice classification (e.g., toys, fruits, vegetables, flowers, leaves, shells, buttons, sponges, counting manipulatives, stones, keys, kitchen utensils, tools, cutouts of geometric shapes, natural vs. manufactured items, items of clothing).
2. Instruct individual students to examine each object, looking for their **observable characteristics**. In other words, have them describe the objects by characteristics such as color, shape, texture, and size.
3. Have each student in the group describe the characteristics of one object to the other group members.
4. Tell each group to put all items into two piles depending on the similarities and differences of their observable characteristics (e.g., all large objects in one pile and all small ones in another; all red objects in one pile and all non-red objects in another; all objects with wheels in one pile and all objects without wheels in another).
5. Help students discuss the criteria that they used to separate the items.
6. Direct students to construct a dichotomous key (or chart) similar to the sample provided in Classification Activity 1. They should classify objects until all items have been separated singularly. (Note: When this process skill is being introduced to students for the first time, the key can be developed by the whole class, with coaching from the teacher. Once students gain experience with the classification process, the chart should be completed in small groups and/or individually for more effective practice of the skill.)

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Extension activities about classification

After students complete their charts, do one or more of the following:

- Introduce new, related objects (limit of three). Have students "test" their charts by adding the new items to it.
- Instruct a representative from one group to read a description (i.e., the characteristics) of an object on their chart to the entire class. Then have classmates determine which object is being described.
- Place sets of different kinds of objects at different stations. Have groups of students rotate from station to station, developing a chart for each set. Later, have them compare and contrast all the charts from each station.
- Have each student choose from the group's objects 5 items that share a common observable characteristic. Then have group members deduce which characteristic all 5 items share.

PROBLEM-SOLVING SKILL DEVELOPMENT

In the last section, titled "Process Skill Development," we discussed how learning the **content** isn't enough for students to employ the scientific process. We described how teaching **process skills** is appropriate and often necessary for students to have a strong enough foundation to solve scientific problems. Likewise, it is often appropriate to teach students about **solving problems**. In addition, by teaching students a process for solving problems, we are teaching them how to solve problems in non-science areas as well. Therefore, instruction about problem solving provides an easy and effective method for **integrating subject matter**. For example, when designing and reporting about their invention, a team of students can use communication (English), science, math, computers, social studies, and others subjects. By conducting integrated learning activities, such as solving problems, we are helping to prepare students for the workplace—where integration is an everyday occurrence. And as our world becomes increasingly technology-rich, skills like those listed in the next paragraph will become critical to students' ability to perform *any* job. Obviously, the development of problem-solving skills is imperative for every student.

For these reasons, the authors have included some basic problem-solving information. The general concepts are outlined below. Practice activities for students in solving problems can be found in Appendix E, pp. 335-352.

Identifying Problem-Solving Skills

Teachers can help students develop the skills needed for becoming both scientific thinkers and effective worksite problem solvers by providing opportunities to **practice solving problems**. Success in such areas requires people to develop the ability to:

- **Understand cause-effect relationships**, e.g., what parts of systems affect and are affected by other parts?
- **Make comparisons**, e.g., what commonalities and differences do systems have?
- **Recognize probable outcomes**, e.g., how will the system react to a specific action?
- **Predict what should happen next**, e.g., based on what has been observed, what is known about a specific system, and what is known about related scientific principles, make a prediction about what will happen next.
- **Judge spatial relationships**, e.g., visualize how a system operates and mentally rotate system parts to solve problems within a given system.
- **Notice what appears out of place**, e.g., observe a malfunctioning system in operation and identify the source of the malfunction.

Strategies for Helping Students Practice Problem Solving

To become expert problem solvers, students must be given opportunities to develop and refine such skills. Options for providing and promoting problem-solving practice are limited only by our creativity. The following guidelines may be helpful in stimulating your ideas:

- **Minimize instructions** so that students are encouraged to invent innovative ways to accomplish their tasks.
- **Provide students with a variety of materials** from which to choose.
- When students have questions, **repeat the initial instructions without giving further information**. This strategy encourages students to search for and/or create their own solutions.
- **Allow plenty of exploration time**. As long as students are actively engaged, learning is taking place. In addition, when ample time is given, students can pursue deeper levels of investigation.
- **Encourage students to share ideas with each other**. This strategy reflects how people solve problems in the workplace—with input from others. Most problem-solving activities lend themselves to having students work individually or in pairs. Occasionally, it is appropriate for students to work in small groups of 2-4. When students work individually, they should be encouraged to seek others' input. (Note: Remember to organize students into both same-gender and mixed-gender groups. See "Gender Equity: What Can I Do?" in Appendix D, pp. 329-334, for more information.)

A Problem-Solving Model

The IDEAL[8] model, which is described below, is one well-known aid for teaching and improving problem-solving skills. It guides students through the problem-solving process. The IDEAL process includes the following steps:

- I = **Identify the problem** (e.g., determine what needs to be done).
- D = **Define and represent the problem** (e.g., sharpen and clarify the boundaries).
- E = **Explore alternative approaches** (e.g., analyze and evaluate alternatives).
- A = **Act on a plan** (e.g., determine the logical steps to be used and how to progress through the steps).
- L = **Look at the result** (e.g., determine whether or not the plan worked).

Problem Solving Practice

A variety of problem-solving practices, which use design, invention, and black-box activities as their foundation, are located in Appendix E, pp. 335-352. Also refer to the resource lists in Appendix B, pp. 293-314, for books, kits, computer software, and Internet sites that describe additional strategies for helping students practice solving problems.

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[8] *The IDEAL Problem Solver: A Guide for Improving Thinking, Learning, and Creativity* (1984).

Summary

In this section, Learning Concepts and Strategies, *Fun with Physics* writers have outlined and explained their most effective scientific learning strategies—inquiry-based learning, process-skill development, and problem-solving skill development. These writers suggest some *general* instructional practices, as well—many of which are described in *Science with Reason*.[9] We have summarized a small portion of that information for you below. Feel free to use any or all of these strategies to enhance your science-related instructional strategies.

- Determine what your students already know, then help them to find answers to their questions. Support the concept of not having the answer, both with your students and in modeling the behavior yourself. Tell students that you will find the answer together, when you don't have the information either!
- Know the activity— make a sample, adapt instructions to meet your students' needs, gather and prepare materials, determine the best way to present the activity, and do a "dry run."
- Make a web or use a chart.
- Use KWL: K— what do learners know? W— what do you want them to know? and L— have students demonstrate their learning.
- Remember the powerful statement: "I see and I remember, I do and I understand." It can remind you to use hands-on activities and collaboration in instruction.
- Accept that sometimes you must simply transmit information (e.g., safety considerations). Still, questions can be integrated even in these transmissions. Focus on why or why not, clarifying objectives, discussing alternatives and formulating answers.

---

[9] Summarized from *Science with Reason*, Sue Atkinson and Marilyn Fleer, editors, 1995, p.16.

- Vary instructional settings: whole group, small group, and one-on-one activities, centers, demonstrations, displays, and technology.
- Cross-curricular integration builds excitement, enhances understanding, and maximizes teacher resources.
- Real world, performance-based assessment is a **must**.
- Plan strategies for teacher intervention ahead of time so you will be prepared when students needs assistance.
- Exploration stimulates creativity, fosters comradery, and develops both fine and gross motor skills.
- Build a home-school-learner connection.
- **Make learning fun!**

The general strategies presented here, as well as many of the concepts and strategies outlined in the foregoing pages of this section, can be integrated across the curriculum to enhance the overall learning environment.

FUN WITH PHYSICS:

Real-Life Problem Solving for Grades K-3

How to Use This Book

This section provides practical information designed to help you:

(a) create a plan for using the concepts and learning activities outlined in this book, and

(b) assess the impact of your efforts on your students' learning.

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WHERE DO I BEGIN?

Congratulations on deciding to use *Fun with Physics* as a resource for helping students with science-related learning! The only question is: where to begin? That was a difficult question for the authors to answer, because everyone using this book has a unique blend of experience, ideas, resources, and needs. In the end, authors and pilot teachers developed the following two lists as guidelines. The first organizes the book's information into six broad, sequential steps for implementing science instruction. The second, titled "Helpful Hints," contains the most essential ingredients for success, as derived from the writers' and pilot teachers' collective experience.

Implementation Framework

You may want to think of these steps as the process for building a car. The steps, when taken sequentially, will provide a solid "chassis" for giving students science-related learning experiences. Once you've built the chassis, get creative and have fun installing the "accessories" and applying the decorations!

Step 1 **Help students grasp why becoming an effective problem solver is so important.** Discussions—better yet, demonstrations—of practical, everyday uses of physics in *students'* lives (at school, home, and work) will help them recognize and accept the relevance of physics-related principles.

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Step 2 To help students gain an understanding of the basic principles of physics and problem solving, **structure inquiry-based learning opportunities** that follow the **Five Es of Instruction** format and similar models. Each *Fun with Physics* learning activity follows the Five Es. Remember, the Five Es are:

- Introduce a new concept to students with an **engagement** activity (optional).
- Provide **exploration** activities for students.
- Then, help students **explain** what they learned during exploration.
- **Evaluate** students to make sure they understand the concepts being taught.
- Provide students with opportunities to **extend** their learning to other applications of the concepts and skills that have been learned.

Step 3 **Supplement** *Fun with Physics* **materials** with other science resources. *Fun with Physics* was created as a practical guidebook instead of a comprehensive science resource. Supplemental materials are especially helpful during the explanation and extension phases of the Five Es. (The Resources section, Appendix B, pp. 293-314, suggests materials that offer additional hands-on science activities.)

Step 4 **Check the results of your physics learning activities.** Strategies for assessing your instructional efforts, as well as the importance of checking the learning, are explained on pp. 45-51. This step corresponds with the evaluation phase of the Five Es.

Step 5 **Plan additional instructional strategies for students to extend their learning** to other applications of the concepts and skills that have been learned. This corresponds with the extension phase of the Five Es.

Step 6 Plan **additional instructional strategies for students whose skills did not improve** as much as needed. You may want to seek help from colleagues concerning students who continue to struggle. The problem-solving skills developed through science-related learning are a "must" for success in the real world, so no student can afford to be left behind.

Step 6 Provide **frequent opportunities for all students to practice** physics problem solving.

Helpful Hints

- **Model** problem-solving strategies. For example, explain your rationale for making decisions while solving problems.
- Provide **frequent and varied hands-on practice**, in an atmosphere that fosters curiosity and risk taking.
- **Value** the different and unique ways that students explore.
- Base learning activities on **students' interests**.
- **Instill confidence** in students' abilities to solve problems.
- Provide students with **sufficient materials, information, and space** for learning.

- Provide opportunities for students to **solve problems cooperatively** (e.g., to work individually but share ideas with classmates, to work in assigned pairs, and to work in assigned small groups).

- **Vary practice circumstances** to mirror those found in the work place. Have students work on some tasks individually, some in pairs, and others in small groups of 3-5 students.

Notes

ASSESSMENT

Checking the results of your solution is an essential part of the problem-solving process. In the same way, **assessing learning** is a key component of successful science instruction. Without assessment, *Fun with Physics*, like any learning tool, loses much of its value. In the context of this book, assessment will:

- Evaluate students' understanding of scientific content and processes before, during, and after instruction
- Evaluate the effectiveness of learning strategies (e.g., Have learning objectives been met?)
- Guide future instruction (e.g., Which extensions will meet the needs of my students?)
- Identify students' unmet learning needs (e.g., Do the students understand the principle that has been taught? If not, what can be done to help them learn this principle?)

Assessment lets **both** you and the student determine whether the learning objectives have been met. It also provides a sense of accomplishment and directs further learning.

Assessment **strategies** can vary—depending on the age and skill levels of the students and instructional style of the teacher. The strategies you use are a matter of choice. Some methods are described below.

Journaling

Students assess their own learning by recording their reflections about the **process** used to explore scientific principles, and the **generalizations** and **conclusions** they made from the experience. In addition, journals help students to **apply** what they learn to their home, school, and community, as demonstrated in the following examples of 3rd grade journal entries. The students were beginning a new unit on simple machines by exploring inclined planes.

This inclined plane is 48 in. long. First we dropped something heavier on it then something light. I think gravity is causing this or maybe not. It might be the air curents. It might have something to do with the shape. Nobody knows for shure.

It seems to me that if the distants is longer it makes it easier to lift. If you cut the steepness in half it will take you longer but it takes less effort.

Journal prompts are provided in each *Fun with Physics* learning activity.

Worksheets and/or data sheets

As a way to determine students' **knowledge** of the principles being taught, teachers can collect and grade information sheets that are completed during scientific explorations.

Presentations

To summarize what they've learned, individuals or teams of students present their **findings** to others, including **conclusions** drawn from the findings.

Interviews

The teacher conducts one-on-one discussions with students, during which they can describe their **understanding** of what they have learned and the **applications** to everyday life.

Quizzes

Quizzes are a quick and effective way of checking students' **knowledge** of scientific principles with objective testing. They do not, however, assess process skills.

Teacher observations

As a performance-based assessment, the teacher visually monitors students as they solve problems. Teachers can see students' abilities to employ process skills, attain behavioral objectives, and work in teams—and more. Any of the *Fun with Physics* learning activities can be used to assess student learning through observation. In addition, the design activities described in Appendix E, pp. 335-352, can be used to assess students by observing them. The Observation Sheet on p. 50 can be used to record students' knowledge of content and ability to employ process skills. It can be adapted for use with other types of skills, as well.

Teachers may wish to develop their own assessment tools to identify and record skills of their students. In addition, the authors have provided two assessment forms, which are included in this section:

- Instructor Record Sheet
- Individual Student Observation Sheet

Instructor Record Sheet

Instructions: Teachers can use this form to record what students have learned and what they can do.

1. Write each student's name in the column on the left.
2. List the learning areas to be evaluated (e.g., specific process skills, content knowledge, other applications to real-life physics problems) across the top row.
3. Assess each student's ability to use the listed knowledge and/or skills in solving physics problems, using the following standards:

IN = student can apply content to solve problems **in**dependently
WA = student can apply content **w**ith **a**ssistance
CN = student **c**an **n**ot apply content to solve problems

Areas to be evaluated ▼ **▼ Student's name**								

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Individual Student Observation Sheet Instructions

The Individual Student Observation Sheet lists the process skills for science. Open spaces are provided for additional, content area objectives. This assessment tool can be used in the classroom to effectively:

- guide teacher observation of specific process skills and knowledge of content,
- document each student's progress, and
- measure the amount of individual student progress from previous work to the current learning activity.

Each student's progress is evaluated individually. Results should be used to plan future instruction. Observation sheets for individual students can also be useful in assigning students to homogeneous or heterogeneous groups for small-group instruction.

Instructions: Please read completely before use.

1. Create an Observation Sheet for each student.
2. Complete the "name" and "unit" blanks, e.g., the student's name and the unit or topic to be learned.
3. Before beginning a unit, observe students using the process skills listed and record findings in the column labeled "before." Be sure to date this column. Use the standards that follow or develop your own:

   IN = student can apply content to solve problems independently
   WA = student can apply content with assistance
   CN = student can not apply content to solve problems
4. During the unit, make another observation and record findings in the "during" column. Use the same standards as you used in the pre-instructional observation. Remember to date it.
5. As the unit culminates, make another observation, recording findings in the "after" column. Again, use the same standards as you used in the pre-instructional observation. Remember to date it.
6. Analyze and compare the data obtained during observations.

Hint: For ease of recording and making use of this observation sheet, use different colors of ink when completing each recording date and its data.

Individual Student Observation Sheet

Student's Name ______________________________

Unit ______________________________

Instructions: See page 49.

Standards:
IN = student can apply content to solve problems **in**dependently
WA = student can apply content **w**ith **a**ssistance
CN = student **c**an **n**ot apply content to solve problems

Make one copy of this sheet for each student being assessed. Use a different color of pen and note the date each time you record your observations.

Process Skills	**Date_____** **BEFORE**	**Date _____** **DURING**	**Date_____** **AFTER**
Building models: Constructing a physical or mental representation to explain an idea, object, or event.			
Categorizing or classifying: Grouping or ordering objects or events according to an established scheme, which is based on observations.			
Communicating: Giving or exchanging information (e.g., insights, explanations, results of observations or inferences, measurement) to others verbally, pictorially, or in writing.			
Comparing: Relating one thing to another so that similarities and differences can be identified.			
Controlling variables: Manipulating one factor that may affect the outcome of an event while other factors are held constant.			
Experimenting: Use observations to collect and analyze data in order to draw conclusions and solve a problem.			
Hypothesizing: Stating a problem to be solved as a question that can be tested by an experiment.			

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Date_____ Process Skills	Date _____ BEFORE	Date_____ DURING	AFTER
Inferring: Developing ideas based on observations and suggesting explanations, reasons, or causes for observed events.			
Interpreting data: Using the data collected during scientific investigations to answer questions about a scientific investigation.			
Measuring: Comparing objects to arbitrary units that may or may not be standardized.			
Observing: Using one or more of the senses to gather information. May include the use of equipment.			
Ordering: Using observed characteristics to organize objects or systems in a sequence.			
Predicting: Forming an idea of an expected result. Based on prior observations and inferences.			
Recognizing relationships: Interpreting interactions between different components of a system.			
Recording: Creating a written record of observations made during experimentation, including diagrams and/or graphs.			
Content: ______________________			
Content: ______________________			
Content: ______________________			
Content: ______________________			
Content: ______________________			
Content: ______________________			
Content: ______________________			

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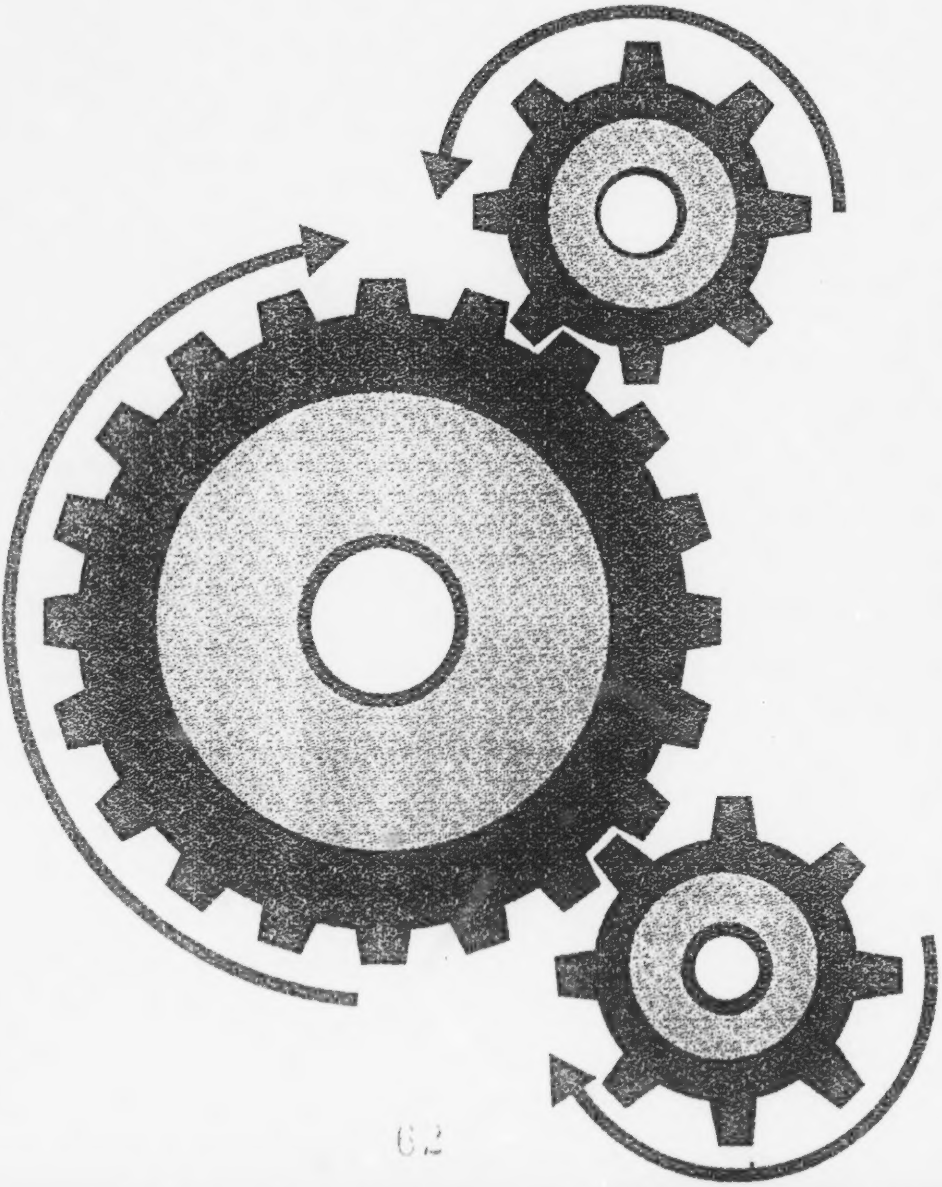

FUN WITH PHYSICS:

Real-Life Problem Solving for Grades K-3

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What's Going On In There? 101

Wacky Inventions 111

NOTE: Teachers may want to treat the learning activities in this section as a unit. The learning activities are listed in order of progressive difficulty. The first activity is an introduction to the topic of Exploring Simple Machines. The next four activities involve specific simple machines. The last two learning activity help students pull together and apply the concepts they've learned in previous activities.

SIMPLE MACHINES VOCABULARY

Energy

- Potential energy
- Kinetic energy

Force

Friction

Gear

Inclined plane

Inertia

Lever

Machines

Pulley

Simple machines

Wheel and axle

Work

MACHINE SCAVENGER HUNT

Topic: Investigating common, simple machines

Learning objectives

Students will:

1. Name familiar machines.
2. Identify the functions of familiar machines.
3. Recognize how machines can expand human abilities.

Process skills

○ Building models
● Categorizing or classifying
● Communicating
● Comparing
○ Controlling variables
○ Experimenting
○ Hypothesizing
○ Inferring
○ Interpreting data
○ Measuring
● Observing
○ Ordering
○ Predicting
● Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
○ 3
● 4
○ 5
○ 6
○ 7
● 8
○ 9
○ 10
○ 11
○ 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup..................10 minutes
Exploration..........55 minutes
Cleanup..............10 minutes

Key science principle

- Machines extend human ability

Materials

A large piece of construction paper or a sheet of flip chart paper

Markers

Blank 8½" x 11" paper (or clue sheets)

Pencils

Pictures of machines (Pictures can be found in the books listed in the Resources sections of this learning activity and in Appendix B.)

Safety tips

✚ Help students to understand that **all** machines must be handled with respect and caution. *Hint: Read an autobiographical article or show a video about the damage inflicted by a machine's power when it was misused and/or disrespected.*

Engagement activities

1. Provide an overview of how machines are involved in students' everyday lives.
    a. Begin a class discussion about machines by asking students, "What is a machine?" Record their answers on construction or flip chart paper.
    b. Next, explain to students how machines help us perform our jobs and make them easier (i.e., machines do **work**). Ask students to find and name some machines located in the classroom and what task each helps us to perform (e.g., pencil sharpener, door knob, tape dispenser, light switch). This time, have students record their answers in their journals.

c. Then show pictures of both machines (e.g., telephone, can opener, vacuum cleaner, camera or clock) and non-mechanical objects (e.g., chair, trash can, bread box, towel, plant). *Hint: You can cut pictures from magazines and paste them on construction paper or show students pictures and/or drawings of machines in books.* As you show each picture, ask students to identify whether the object is a machine. Students may struggle at first to recognize the difference. Be sure to encourage them to keep trying. Let them use their own resources and try to figure it out first. Then provide the following guideline to help them: If it is active (i.e., if it **does** something), it is a machine; if it is passive (i.e., it **does not** do something), it is not a machine. Have them write this guideline in their journals and remind them to refer to it when determining if an object is a machine or not. You can also place the machine and non-machine pictures on two different sides of the room as they are identified to provide visual cues for students. Finally, ask students to explain why they believe the object is a machine or non-machine so that they can assimilate the difference.

2. As a further introduction to machines, review each picture again and ask students, "What does it do?"

Exploration activity

1. Divide the class into groups of 3 or 4 students.
2. Instruct them to explore the classroom for about 20 minutes, finding every machine they can.
3. Ask students to designate 1 member of the group to record their findings—either by listing the names of the machines found or drawing each one.

4. Call the groups together as a class and have each student name a machine found by their group.
5. Ask the rest of the students to describe what that machine does.
6. Record the machines named on a flip chart under the title, "Machines in Our Classroom." Hang up the list.

Homework assignment:

1. Talk with students about some of the machines they have at home (e.g., toys, egg beater, VCR, television, can opener, stove).
2. Have students look for machines at home.
3. Students can record their own findings with word or picture descriptions, or ask an adult or sibling to list the machine names for them. *Hint: To enlist the support of parents, send home a note that explains the homework assignment and asks for their support.*
4. The next day, ask students to name at least two machines found around their homes. Again, record their machines on a flip chart under the title, "Machines in Our Homes." Hang it next to the "Machines in Our Classroom" list.

Explanation

Following exploration, help students to verbalize and summarize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraphs will emerge or teach the concepts through enhancement, exploration or expansion activities.

Machines make tasks easier for people by transmitting motion energy or force—creating movement. Let's look at the pencil sharpener as an example. When we turn the handle on the outside, gears move on the inside. That **movement** grinds the wood and pencil lead, creating a writing point.

Although machines surround us, many are *not recognized* as machines. Machines in the classroom include lights and switches, doors with hinges and knobs, pencil sharpeners, and tape dispensers—to name only a few. The desk and standard wooden chair are not machines because they do not **do** anything. Doorknobs are machines because they **transmit** the motion of turning the knob into **moving** the latch to open the door.

Six devices exist in the world of machines that are known as **simple machines**: levers, pulleys, wheels and axles, inclined planes, screws, and wedges. These machines are used to make certain tasks significantly easier. Each is described below. Refer to Appendix C, pp. 315-327, for a more complete explanation.

- **Lever:** A lever is a bar that is supported by a fulcrum (i.e., the support on which a lever turns). When pressure is applied to one end of the bar, the other part of the bar pushes the load. Examples include crowbars, seesaws, nutcrackers, wheelbarrows, and tongs.
- **Wheels and axles:** Wheels are objects that move things (i.e., do work) by using a rolling action. An axle is a pin, bar, shaft or similar object on which a wheel rotates. Examples of wheels and axles include wishing wells, cars, trucks, bicycles, conveyor belts, wheelbarrows, pizza cutters, and can openers.
- **Inclined plane:** A flat surface that slopes is called an inclined plane. The more gradual the slope, the less effort needed to move a heavy object up it. Friction sometimes must be reduced by adding wheels. Examples include the walkway that slopes from the back of a moving van and a skateboard ramp. The skateboard ramp helps to thrust students and their skateboard into the air.

- **Pulley:** Similar to wheels and axles, a pulley consists of one or more wheels and a rope. The rope runs along the outside of the wheels, allowing effort to be applied in a downward direction so that an object (typically heavy) can be lifted up. A one-pulley system changes the **direction** in which an object is moved (e.g. lifting a pail to a roof top). However, one-pulley systems do not make work easier. A multiple-pulley system decreases the amount of effort needed to do work. That is, pulling downward on a rope of a pulley system that uses 2 or more pulleys to lift a pail to a roof top requires less human effort than lifting the object by hand. (The more pulleys, the easier it is to do the work.) Examples of multiple-pulley systems include a block and tackle, a hoist, and a crane.
- **Gears:** Gears consist of wheels with teeth located on their outer edges. Gears rolled against themselves (e.g., their outside edges intertwining) create motion for accomplishing tasks. Examples include bicycles, computer printers, some toys that move, and clocks.

Often more than one simple machine is employed on the same task. For example, a wheelbarrow uses both a lever and a wheel and axle. Much more work can be done (i.e., more weight can be lifted with less human effort) by raising the handle of the wheelbarrow. In other words, the **load** carried can be greater than human effort alone could handle because simple machines are used.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. When you observe, you can visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. Is a desk a machine? Why?
2. Is a pencil sharpener a machine? Why?
3. What guideline can you use to help you decide whether an object is a machine?

Observation: Conduct 1-1 interviews with students, using the object pictures from the exploration activity. Record how many objects the student can identify correctly. Provide coaching, as needed.

Journal assignment: Give an example of a simple machine. Describe the work it does and explain how the work is done.

Extension activities

- Ask students to imagine a machine they would like to invent (e.g., a machine to put away toys at cleanup time). Students can verbally describe their machines, write about them, or draw pictures of them. *Hint: Read* The Cat in the Hat *by Dr. Suess to stimulate students' imaginations for this activity.*
- Provide large sheets of paper, a variety of magazines (e.g., science, technology, general interest), scissors, and glue. Instruct students to create a machine collage by finding and cutting out pictures of machines from the magazines and glue them to the paper.
- Extend the collage project so that students categorize/classify different sets of machines (e.g., food machines, machines with wheels, toy machines, business machines). As a class, graph the different kinds of machines used.

- If any student in the room uses a hearing aid, wheelchair or similar mechanical device, ask the student to demonstrate and/or explain to classmates how the machine works and how it helps the user. *Hint: Be sure to demonstrate respect for the disabled student by requesting his or her support for this learning activity* **in advance**.

Subject integration

Language Arts. Have students create books about the machines they use. Format can be non-fiction, such as labeling the machine and describing what it does through drawings and/or pictures from magazines. Students might also write a fiction book and make the machine the "star" character (e.g., "Sally the Stapler Saves the Day"). To help students develop story ideas, create a story starter that can prompt students to describe a machine's use as a part of a story.

Language Arts. Include fiction and non-fiction books about machines in the classroom library. Some popular picture book titles are listed in Appendix B, pp. 295-307.

Math. Instruct students to list by **category** the different types of machines found in the classroom and home (e.g., food machines, machines with wheels, toy machines, business machines). If you did the Scavenger Hunt activity on pp. 57-58, use that information and ask students to add even more machines to their lists. As a class, graph the results of this activity. Students could gain additional math practice by graphing the machines by category.

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Resources for teachers

What Will Happen If? by Barbara Sprung et al. (Educational Equity Concepts. 1985.)

A New True Book Series: Machines by Fred Willkin. (Regensteiner.)

Parents Are Teachers, Too by Claudia Jones. (Williamson.)

Resources for students

Bam! Bam! Bam! by Eve Merriam. (Henry Holt & Co.)

Machines by Anne Rockwell. (Macmillan.)

Machines at Work by Byron Barton. (Harper Collins.)

Mr. Butterby's Amazing Machines by Pauline Cartwright. (Steck-Vaughn Co..)

The Cat in the Hat by Dr. Seuss.

The Way Things Work by David Macaulay. (Book and CD-ROM.)

Notes

74

WIND 'EM UP

Topic: Potential and kinetic energy

Learning objectives

Students will:

1. Explore potential and kinetic energy.
2. Discover the nature of movement created through potential and kinetic energy.

Process skills

● Building models
○ Categorizing or classifying
● Communicating
● Comparing
○ Controlling variables
● Experimenting
○ Hypothesizing
○ Inferring
● Interpreting data
● Measuring
● Observing
● Ordering
● Predicting
● Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
● 3
○ 4
● 5
● 6
● 7
● 8
● 9
● 10
○ 11
○ 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup . . . . varies
Exploration . 40-60 minutes
Cleanup . . . . varies

Key science principles

- Work
- Force
- Energy

Materials (for each group of 3-4 students)

Small pencil (3-4 inches long) or a crayon
(Hint: golf pencils work well.)

Rubber band

Paper clip

Spool

Word cards for the class science chart (potential energy, kinetic energy, energy, force, machine)

Safety tips

- Review your science lab rules, and remind students to follow them.
- Instruct students to use caution when handling and using materials, to avoid such hazards as getting snapped by the rubber band or scratched by the paper clip.

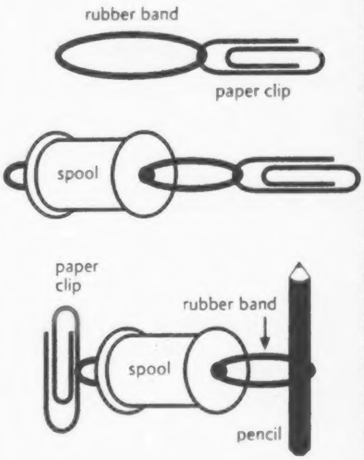
Engagement activities

1. Facilitate a game of "Freeze" with students. Have them stand and then "freeze" in a position. While they stand frozen, explain that they have **potential energy** to move right now. Next, instruct students to "unfreeze" and move around the room. While they are moving, explain that they are using kinetic energy right now. Encourage them to look at one another to observe potential energy and **kinetic energy** during those parts of the exercise. Continue to play the game, but replace the words "freeze" and "unfreeze" with "potential energy" and "kinetic energy."
2. Read *Alexander and the Wind-Up Mouse* by Leo Lionni. Ask students, "When did Willie have potential energy?"

3. Divide the students into cooperative groups of 4-6. Give each group a wind-up toy and ask then to practice potential and kinetic energy. Meet as a class to share the discoveries students made during the practice with questions like:
   - "What happens when you wind the toy and release it?"
   - "How does the toy move?"
   - "How far does the toy move?"

Exploration activity

1. Divide students into groups of 3-4 students each.
2. Explain that each team will build a "Wind 'Em Up" toy (see diagram).
3. Give each group a pencil or crayon, rubber band, paper clip, and spool.
4. Instruct them to attach the rubber band to the paper clip. Demonstrate with your own rubber band and clip, if needed.
5. Have students thread the rubber band through the hole in the spool. If necessary, use another paper clip as a "needle."
6. Place the small pencil (or crayon) through the loop of the rubber band. It should be sticking out of the spool.
7. Pull the paper clip through the other end of the spool. Turn the paper clip perpendicular to the spool, opposite the pencil.
8. Wind the rubber band by turning the pencil.
9. Lay the spool on the ground and release it. *Hint: If energy is directed toward the clip, you may need a lubricant (e.g., hand lotion) to promote movement.*
10. Give the students ample time to explore.



11. Bring students back into a large group to identify when the toy had kinetic and when it had potential energy. *Note: The toy had potential energy when they were winding it or holding it, and that it had kinetic energy when they let go.* Next, help students discover that the more times they wound the rubber band, the farther the toy went. Ask questions like, "What did you do that made the toy go farthest?"

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge. See Appendix C, pp. 315-327, for a more detailed explanation.

- **Mechanical energy,** commonly called energy, is the power to make objects move—so that they do **work**.
- **Potential energy** represents the amount of work an object can do by returning to its original position.
- **Kinetic energy** is the energy of a moving body.
- **Force** is the power that causes an object to move, stop, or change directions.
- A **machine** is a device that makes work easier.

Hint: A Push-and-Go toy can be used to demonstrate potential and kinetic energy. When a button or toy part is pushed, the toy has potential energy (i.e., it can do work when the button or part is released). When the toy is let go, it has kinetic energy as it moves.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. Observation allows you to visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions/written assessment:

1. "Freezing" is an example of which kind of energy, potential or kinetic?
2. Moving is an example of which kind of energy, potential or kinetic?
3. Kinetic energy can make objects go farther. True or false?
4. Have students draw a picture of someone using a wind-up tool (e.g., music box, wind-up toy, Push-and-Go toy) that makes work easier. Review the pictures to assess whether students understand the principle of energy and force.

Observation:

1. Watch students play the freeze game. Record whether they respond correctly to the words "kinetic" and "potential."
2. Observe students practicing movement with their wind-up toys. Record whether they applied knowledge from the freeze game to causing the wind-up toy to move.

Journal assignment: What makes a wind-up toy move?

Extension activities

- Experiment with and discuss the six simple machines that make work easier. *Hint: These were named and explained in the Scavenger Hunt learning activity.*
- Have students decorate wind-up toys. Then hold a "race" to see which toy moves the farthest. As a class, create a chart to record the results.

Subject integration

Language Arts. Collect literature related to different types of transportation machines (e.g., construction equipment, cars, trucks, boats, planes). Create learning assignments that allow students to discover how these machines make work easier.

Resources for teachers

Machine Shop (AIMS) (See the Resource List, p. 296, for ordering information.)

Teaching Physics Through Children's Literature by M. Sarquis. (Triangle Learning Press, an imprint of McGraw-Hill, 1997.)

Bill Nye's web site on the Internet (See the Resource List, p. 314, for the Internet address.)

Bill Nye video on simple machines

Resources for students

Alexander and the Wind-Up Mouse by Leo Lionni.

Mike Mulligan and His Steam Shovel by Virginia Burton.

Bears on Wheels by Jan and Stan Berenstain.

Simple Machines. (CD-ROM 7296)

The Way Things Work by David Macaulay. (Book and CD-ROM.)

Gizmos and Gadgets by The Learning Company. (CD-ROM)

Dig, Drill, Dump, Fill by Tana Hoban.

Notes

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EASY MOVIN'

Topic: How inclined planes work

Learning objectives

Students will:

1. Explore inclined planes.
2. Discover how inclined planes make work simpler.

Process skills

● Building models
○ Categorizing or classifying
● Communicating
● Comparing
○ Controlling variables
● Experimenting
○ Hypothesizing
○ Inferring
● Interpreting data
● Measuring
● Observing
● Ordering
● Predicting
● Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
● 3
○ 4
● 5
● 6
● 7
● 8
● 9
● 10
○ 11
● 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup....................varies
Exploration..........1-2 hours
over 2 days or more
Cleanup................varies

Key science principles

- Work
- Friction
- Force
- Energy
- Inertia
- Inclined plane
- Lever

Materials (for each group of 3-4 students)

Boards in various lengths (e.g., 1 foot, 2 feet, 4 feet)

Fulcrum (e.g., 4″ x 4″ 6-inch post, wooden blocks or books)

Shoe box

Yarn or string (to pull a box of books up an inclined plane)

Spring scale

Books (to be used as weights)

Movin' Up data sheet

Pencil

Safety tips

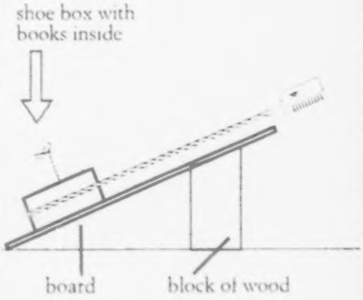
- Review your science lab rules, and remind students to follow them.
- Instruct students to use care when handling and using materials.

Engagement activity

Use the same materials listed for the exploration activity, except choose a 4-foot long, 1″ x 6″ board. Fill the shoe box with weights or books. *Hint: You may want to use similar containers for each student/group of students, depending upon the size of the spring scale.*

1. Tell students that the box needs to be moved from the floor to the desk. Ask, "Do you think this will be hard work?"
2. After several students respond, attempt to lift the shoe box with two hands (and/or ask a student to try).
3. Next, use the 1″ x 6″ board as an inclined plane to lift the shoe box. (Have a student try it, too.)
4. Then discuss what happened, helping students recognize that the inclined plane is a simple machine that makes work easier.

5. Transition into the exploration activity by explaining that students will have an opportunity to explore inclined planes further.



Exploration activity

1. Give students time to explore the spring scale, if it is new to them. Explain that it measures how much work is being done.
2. Review what happened in the engagement activity.
3. Divide the class into teams of 3-4. Assign roles to each member, e.g., recorder, reporter, scale reader, and materials manager.
4. Challenge the students to use the materials provided to move the weight/books in the easiest possible way. Be sure to define the meaning of "easiest" for purposes of this exercise.
5. After students have had ample time to explore, give each team a data sheet (*Movin' Uphill*) and have them compare the length of the boards and the force used. **This step may not be appropriate for students in grades K and 1.**
6. When all results are recorded, have the teams share their findings with the total class. Record the class's results on a large chart.

Explanation

Following exploration, help students to verbalize what they learned. The following definitions may be helpful to teachers when facilitating discussions about this learning activity. More detailed information is available in Appendix C, pp. 315-327.

- **Energy:** the power to do work
- **Force:** the power that causes an object to move, stop, or change directions
- **Friction:** the force that slows down a moving object as it is making contact with a surface

- **Gravity:** the force that pulls things toward the ground
- **Inertia:** the force in an object that helps it to resist stopping if it is already moving or to resist moving if it is stopped
- **Lever:** a bar (set on a fixed point) that can be moved to help lift heavy objects or move other objects
- **Machine:** a device that makes work easier

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. When you observe, you can visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions/written assessments:

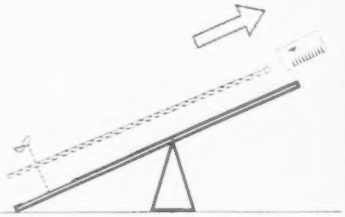
1. Which lever makes lifting easiest, a shorter one or longer one?
2. Can you lift more weight with a lever and inclined plane or with two hands? Explain.
3. Use the Movin' Uphill data sheet to evaluate learning.

Observation: Observe students as they practice moving the weight and lifting each other using levers and inclined planes. See if they are making conclusions about the length of the board and the placement of the fulcrum.

Journal assignment: What is a lever? How do levers make work easier?

Extension activities

- Direct students to explore how friction affects the movement along an inclined plane. For example, use sandpaper and waxed paper on an inclined plane. Have students pull a box of books up each inclined plane and use a spring scale to measure how much work is being done. (Or use miniature toy cars to run down a board—measuring how far each car travels beyond the end of the board. (Note: The greater the distance, the less friction is on the board.) During class discussion time, be sure to note the differences due to changes in friction. This activity is an excellent way to introduce the Grand Prix learning activity, which follows.
- Conduct a similar exercise to the exploration activity—only this time, using levers. Use a 2-foot board with an eyelet screwed into one end. Place a fulcrum (made from books or a wooden block) under the board. Attach a spring scale to the eyelet. Put one or more books on the other side. Have students pull down on the scale and record their findings. Next, have them move the fulcrum and observe which position makes work easiest.
- Have students graph the results of either the exploration or extension activities. For example, they could plot the scale readings for pulling their books up short boards compared to long boards.



Subject integration

Language Arts and/or **Social Studies**. Have students design (by drawing) a simple machine and write a story describing how/why it will help the world.

Health. Study the human body to help students to discover that it works like simple machines.

Resources for teachers

Bill Nye's web site on the Internet (See the Resource List, p. 314, for the Internet address.)

Bill Nye video on simple machines

Simple Physics Experiments with Everyday Materials by Judy Breckenridge.

Physics for Kids: 49 Easy Experiments with Mechanics by Robert W. Wood.

Playground Physics by Evan Moor. (ISBN1-55799-301-7)

Resources for students

The Little House by Virginia Burton.

5-A-Day Adventures by Dole Foods. (CD-ROM)

Bears on Wheels by Jan and Stan Berenstain.

Simple Machines. (CD-ROM 7296)

The Way Things Work by David Macaulay. (Book and CD-ROM)

Gizmos and Gadgets by The Learning Company. (CD-ROM)

Dig, Drill, Dump, Fill by Tana Hoban.

Movin' Uphill Data Sheet

Name of Materials Manager: ______________________________

Name of Materials Manager: ______________________________

Name of Recorder: ______________________________

Name of Reporter: ______________________________

Name of Scale Reader: ______________________________

Use the following materials to do your investigation: *boards, books, shoe box, spring scale, yarn.*

Question: *Which inclined plane moves the book uphill with the smallest amount of force?*

Prediction:

Experiment: (e.g., outline the steps in your experiment, illustrate it.)

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Movin' Uphill Data Sheet—page 2

Results:

The scale read ________ with the shorter board and _________ with the long one.

The scale read ________ with the less steep board and _______ with the steeper one.

Conclusion: (which inclined plane made the job of moving the book uphill easier?)

Assessment:

Answer the following questions individually (NOT as a team).

Can you think of a way to make moving the books easier? Record your ideas below.

Think about your group's experiment. Then circle your opinion of how your team did in the areas listed. Circle ONLY one symbol for each area.

	Good	**Okay**	**Poor**
1. We helped each other.	☺	😐	☹
2. We worked quietly.	☺	😐	☹
3. We worked carefully.	☺	😐	☹
4. We all worked.	☺	😐	☹
5. We cleaned up when we finished.	☺	😐	☹

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GRAND PRIX

Topic: Factors that affect the distance an object travels (See the learning objectives below.)

Learning objectives

Students will:

1. Study elements of a model car's construction.
2. Conclude that construction elements directly impact the distance the model travels.

Process skills

● Building models
○ Categorizing or classifying
● Communicating
● Comparing
● Controlling variables
● Experimenting
● Hypothesizing
● Inferring
● Interpreting data
● Measuring
● Observing
○ Ordering
● Predicting
● Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

○ 1
● 2
○ 3
○ 4
○ 5
● 6
● 7
● 8
● 9
● 10
● 11
● 12

Refer to Appendix F, p. 253, for a description of outcomes.

Estimated time

Setup . . . . 20 minutes
Exploration . 20-40 minutes
Cleanup . . . . . . 10 minutes

Key science principles

- Simple machines (wheels, inclined planes)
- Motion
- Newton's law of motion

Materials

Set of LEGO® or K'nex® (be sure the set includes wheels of various sizes)

Magazine pictures of race cars

Stickers of one color or design (or masking tape marked with a specific color or design)

6" x 6" squares of ½" or 1" graph paper

Crayons or markers

Masking tape

Grand Prix data sheets

3' x 6" wood plank (approximate)

Several building blocks

4' length (approximate) of plastic race track (optional)

Safety tips

- Choose a LEGO® or K'nex® set in the correct size for the students in your classroom. (Small parts sometimes find their way into the mouths of younger students.)
- Supervision may be needed to assure that all materials used in this lesson will be used appropriately.

Note: Don't let the complexity of this activity keep you from doing it with your students—they'll **love** *it!*

Engagement activity

Three or four days before conducting the "Grand Prix" learning activity, set up a center with the following:

- a set of LEGO® or K'nex® blocks that includes wheels of different sizes
- magazine pictures of race cars
- 3-foot x 6-inch wood plank (approximate)
- several building blocks
- plastic race track (optional)

Provide ample time and facilitation in the center for students to discover the different ways to construct cars and to explore the use of a ramp when racing their cars.

Note: This is an activity during which girls may become passive observers instead of active participants. Or they may avoid the center altogether. Teachers should take an active role in encouraging girls to participate in the center activities. (Refer to Appendix D, pp. 329-334, for additional information on instructional strategies that promote gender equity.)

Hint: You may wish to give the pretest described in the evaluation section, p. 88, after students complete this engagement activity.

Exploration activity

Part I: Demonstration

1. Using LEGO® or K'nex® blocks, build a simple car for the class.
2. After demonstrating how to build the model car, have students make predictions by asking, "What will happen when I place the car on a plank?" Let a few students provide verbal answers.
3. Put the car on a wood plank resting flat on the floor. Ask students to observe the motion of the car. *Hint: The car won't move on a flat surface.*
4. Next have students make another set of predictions by asking, "What can we change to make the car move?"
5. Demonstrate the first correct response (probably to put something under one end of the ramp so it inclines).
6. Mark where the car stops with a sticker (or masking tape). Mark it with a "T" for teacher.
7. Facilitate a brainstorming session about what other changes to the car can be made to help it travel a longer distance (e.g., size of wheels, shape of the car, height of the car). Record the suggested changes on a chart.
8. Choose a variable listed on the chart. Encourage students to explain how to make the change indicated.
9. Follow their directions in making the adjustment(s).
10. You may want to ask for predictions about how much farther the car will go with this change in place. Or ask students to write their predictions in their journals.
11. Put the car on the ramp and help students to observe the difference.
12. Mark the distance traveled by the modified car/ramp with a sticker (or masking tape). Mark the sticker with a "T-2" for teacher-trial 2.

Part II: Group exploration

1. Divide the students into groups of 3-4.
2. Explain that each group will work cooperatively to:
   - construct one car,
   - test it on the wood ramp, and
   - mark the distance with their group's sticker.
3. Assign **roles** in the groups: recorder, launcher, catcher and reporter (the latter will report the team findings to the total class). All team members are car designers.
4. Have materials handlers choose **materials** for their team, including: LEGO® or K'nex® pieces, magazine pictures, stickers (or masking tape), graph paper, crayons or markers, and a Grand Prix data sheet.
5. Have recorders lead their teams in choosing a **team name** and simple **logo** (e.g., star, happy face, "z" for fast) and recording them on the team's data sheet. *Hint: Teachers of younger children may wish to assign a logo at the time when roles are assigned.* Once the information is recorded on the data sheet, have team members draw their logo on a few stickers, leaving room for writing a distance traveled on each sticker.
6. While recorders work on step 5 above, build a "Grand Prix Test Field" in an easily accessible area of the room.
   - Prop up the ramp with several blocks or books.
   - Mark the starting line with a strip of masking tape. Label it with a marker. *Hint: Be sure to explain to students that their ramp or car must be positioned on this line for consistency in the experiment. Correlate your explanation to the real world by explaining that scientists always create consistent conditions in their experiments for the same reason.*

- Run a strip of masking tape* (3-inch wide works best) from the starting line to the end of the space available for car travel. Create a distance ruler by writing each inch on the masking tape with a marker.

7. Bring the catchers to the "Grand Prix Test Field" and show them the masking tape distance ruler, explaining that when they retrieve a car, they must place one of their team's stickers beside the ruler and on the spot where the car stops, write the distance on the sticker (e.g., the number that falls **closest** to their car—whether the number is ahead of or behind their car), and give that number to the recorder.
8. Conduct a practice run with each catcher, using a miniature toy car, to make sure they all understand the rules.
9. Instruct recorders to keep up with their teams, writing down the trial number, the changes made to the design of the car, the team's prediction of how the design change will affect the distance traveled, and the distance achieved.
10. Give the groups adequate time to build their cars, make predictions, test them, make changes to their cars, retest, and record their test data. *Hint: Remind students that they can use the chart they created in the demonstration part of the exploration activity for change ideas.*
11. When testing time runs out, instruct each group to formulate conclusions based on their trials. Have the recorder write the final conclusions on the data sheet.
12. Have each group make a drawing of their best car (e.g., the one that went the longest distance) on the graph paper. Be sure that they use one square for each LEGO® or K'nex® block used in the car. *Hint: Younger students may need to simply trace their car onto the graph paper.*

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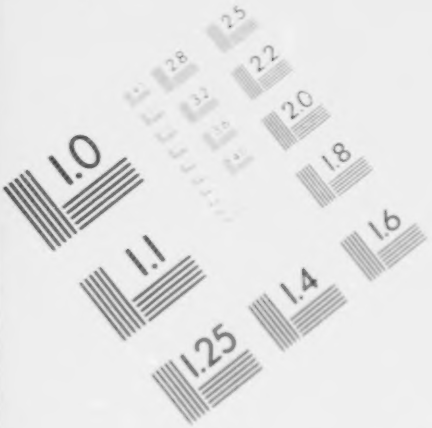
*See the first and second extension activity for another option.



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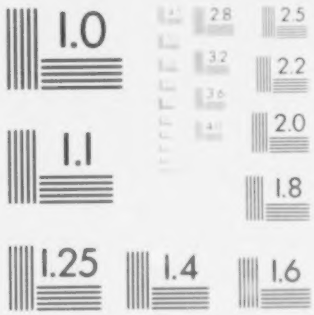
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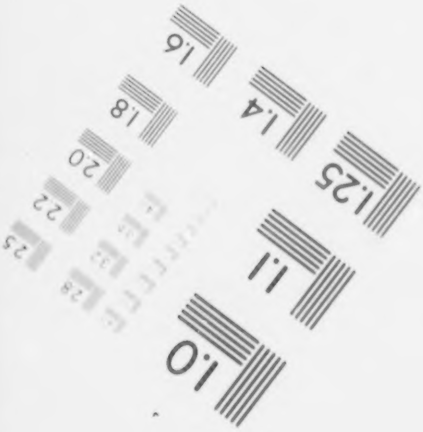

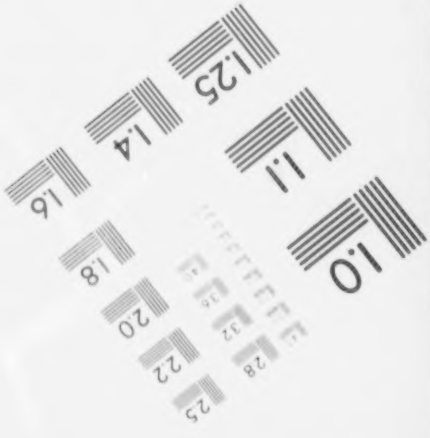

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13. Glue each group's drawing along the bottom of large paper to make a class chart. (This chart can be used for graphing in extension activities.)
14. Bring the groups together for sharing and discussion. First, let each group display their best car. Then have each group report their results and answer questions like:
    - "What made your car go farther?"
    - "What did you try first?"
    - "What did you change?"
    - "Did the change make the car go farther?"
15. Finally, compare the construction of each group's car against the other groups' designs (e.g., size or shape of the car, size of the wheels). Help students correlate the design characteristics to the distance the car was able to travel.

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraphs will emerge. Refer to Appendix C, pp. 315-327, for more detailed information.

Changes in wheel size and shape, as well as car size and weight, can affect the distance that the car travels. A car's shape and weight can affect the center of gravity, thereby slowing or quickening the car's pace. It could also throw it off track. Alterations to the wheels result in a quicker or slower pace, too.

Newton's law of motion states that an object will remain at rest unless acted upon by an outside force. Every action or force is accompanied by an equal and opposite reaction or force. When a force acts on an object, it changes the momentum of that object.

Thus, when the car is placed on a level surface, the **force of gravity** pulls down and is equal to the opposite force of the surface, so the car does not move. A car will roll farther on a ramp that has a steeper incline. The car picks up speed and is moving faster when it reaches the end of the plank and is able to maintain speed until an outside force interferes (e.g., friction from carpeting, an obstacle). The force of gravity acts on the car as it goes down the ramp. The amount of this force is equal to the weight of the car.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. Observation allows you to visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. Do larger wheels make the model car go faster or slower?
2. Would square wheels slow a car down or make it go faster? Why?
3. Which car shapes helped the cars go faster?

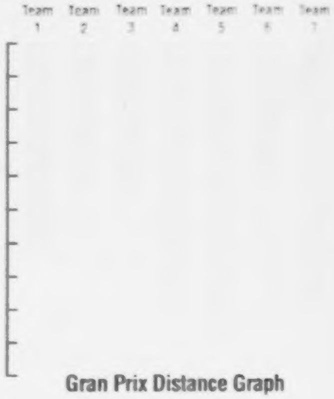
Observation: Conduct a pretest and post-test, and compare the results.

- Pretest: After demonstrating that a car does not move on a flat surface, ask the students to generate a list of ideas that will cause the car to move the farthest down a ramp.
- Post-test: Conduct the pretest again and compare the results to determine the extent to which learning took place.

Journal assignment: Explain (or draw) a car that will travel down a ramp very quickly. Explain what about the design will help it go fast.

Extension activities

- Use adding machine tape to measure the distance of each group's best car (e.g., the one that went the farthest). Tape the adding machine tape to the top of the plank. Tape it in a few places between the plank and the end of the tape to hold it in place. Make the adding machine tape longer than a car could travel. Use a marker or crayon to mark the distance traveled by each car on the adding machine tape, then cut it at the crayon mark. Have each team put their group name and logo on the top of their tape. Use a new adding machine tape for each group's car. When you have created a tape for each group, post them side by side on a board or wall to create a graph. Help students use the graph to compare results. (See the Grand Prix Distance Graph illustration.)
- Complete the Grand Prix exploration activity as outlined, except substitute adding machine tape instead of the masking tape measurer. Make markings one foot apart on the adding machine tape. Then have each group build their car and predict to the nearest foot how far it will travel. Students can record their predictions on their data sheet. After the test run, have students record the actual distance to the nearest foot. Have teams continue to make changes to their cars, predict distances, record them, test, and record the actual distance for 2-4 trials, as time allows. Help teams identify and record their conclusions.
- Instruct each group of students to make a graph that compares the number of times they tested their car and the variables that were changed each time.



Gran Prix Distance Graph

- As a culminating activity, hold a Grand Prix race. Have the class develop and negotiate the rules for the race. A ruler or yardstick can be used to prop the cars across the top of the ramp. Remove the ruler or yardstick to release the cars—and the race begins! Help the winning team discuss the attributes of a good race car with the rest of the class.

Subject integration

Language Arts and/or Music. Younger students may enjoy reading and singing "Watch the Wheels Go Round." *1-2-3 Science: Science Activities for Working with Young Students* by G. Bittinger. (Warren Publishing House.)

Music. Sing a song about machines: "My Favorite Machine." *Piggyback Songs* by J. Warren. (Warren Publishing House.)

Language Arts. Include books about motion and vehicles in the classroom reading/writing center. Ask students to write (or dictate to the teacher) stories with an experience similar to that of Mr. Gumpy in *Mr. Gumpy's Motorcar.* The problem presented in the story might involve changing the character's car or building a ramp to make the car go farther.

Social Studies. Read about the lives of Mario Andretti and Bobby Rahal. Conduct group discussions or team presentations concerning what students have learned about these two successful race car drivers and how science has affected their careers/lives.

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Resources for students

Play and Find Out About Science: Easy Experiments For Young Students by Janice Van Cleave. (John Wiley & Sons, Inc., 1996.)

Physics For Every Kid: 101 Experiments in Motion, Heat, Light, Machines, and Sound by Janice Van Cleave. (John Wiley & Sons, Inc., 1991.)

Junior Science: Sliding and Rolling by T. Jennings. (Gloucester Press, 1989.)

Grand Prix Data Sheet

Team Name: ______________________

Team Logo:

Trial	Changes Made	Prediction	Distance the Car Traveled
1			
2			
3			
4			

Conclusions:

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TRAPPING BEARS

Topic: Learning about gears

Learning objectives

Students will:

1. Construct a bear trap using gears and a berry basket.
2. Demonstrate knowledge about how gears work.

Process skills

- ● Building models
- ○ Categorizing or classifying
- ● Communicating
- ● Comparing
- ● Controlling variables
- ● Experimenting
- ● Hypothesizing
- ● Inferring
- ○ Interpreting data
- ○ Measuring
- ● Observing
- ○ Ordering
- ● Predicting
- ● Recognizing relationships
- ○ Recording

Ohio 4th-grade science proficiency outcomes

- ○ 1
- ● 2
- ○ 3
- ○ 4
- ● 5
- ● 6
- ● 7
- ● 8
- ● 9
- ● 10
- ○ 11
- ● 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup . . . . 20 minutes
Exploration. .30-40 minutes
Cleanup . . . . . . 10 minutes

Key science principles

- Newton's law of motion
- Use of simple machines

Materials (for each group of 3-4 students)

1/8" dowel, 6-8" long

1" bead

Match stick or peg

Cord or string

Tape or glue

Corrugated cardboard (12" x 18")

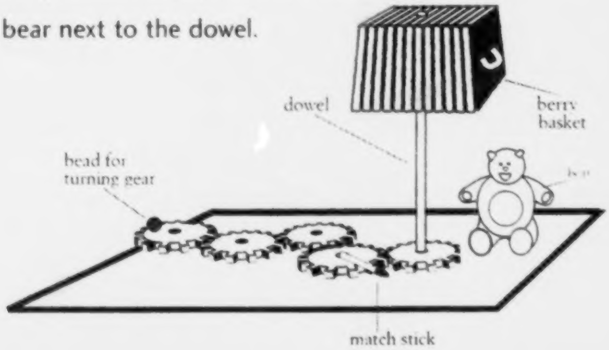
Small plastic or stuffed bear

Berry basket (can be found in the produce department of grocery stores)

Gears (can be found in toy stores or science supply houses)

Instructions for assembling the bear trap:

1. Poke a 1/8" hole in the corrugated cardboard with a sharp object. The hole should be approximately 3" from one edge of the cardboard.
2. Insert the dowel into the hole. Making sure that the dowel is straight, glue it in place with hot glue or wood glue. Let it dry completely.
3. Glue a bead onto the flat surface of a gear. Let it dry.
   Hint: The bead will be used as a knob for turning the gear.
4. Balance the berry basket on top of the dowel.
5. Position the bear next to the dowel.



Safety tips

- Choose parts that are the correct size for the students in your classroom to handle. (Small parts sometimes find their way into the mouths of younger students.)
- Supervision may be needed to assure that all materials used in this lesson will be used appropriately.

Engagement activities

1. Create a gears center to be visited by small groups of students. Give students a set of gears and floor or table space for working with them. Provide free time for exploring the gears and discovering how they work. Encourage students to try the gears on different surfaces and arrange them in a variety of patterns. Observe students' exploration and help them to draw conclusions about the placement of gears and how gears can help with work tasks. *Hint: A kit called GEARS, GEARS, GEARS Factory is especially good for this activity. It includes gears of 3 different sizes, bases for the gears, handles, and more. This kit is available from Wm. Sheridan & Associates and other suppliers of science materials. See Appendix B, pp. 311-313, for information about suppliers.)*
2. Introduce the term "rotation" with a demonstration. Options include having a student use a sit-n-spin toy, operating a large top, showing the rotation involved in a door knob, and showing a film about things that rotate.

Exploration activity

1. After students have experimented in the gears center for a few days, ask them to describe what they have learned about gears. You could use questions like:
    - "What did you learn about how the gears are placed?"
    - "How are gears like wheels?"
    - "What can gears help us do?"
2. Record the responses on chart paper.
3. Have students continue to use the gears center, but ask them to help you solve a problem: "How can I use gears and a berry basket to trap a bear?"
4. Explain to students that you will be adding some new items to the center. Introduce the corrugated cardboard, gears, bear, and berry basket as described in the instructions presented in the materials section.
5. Divide students into small groups. Instruct each group to assemble a bear trap.
6. Once the groups have built their traps, encourage them to try different gears in different ways until they discover one that traps the bear. *Hint: Students must experiment with placement of the gears until they discover that when the gear with the trigger is placed close enough to the dowel, the trap will fall as the gears are turned.*

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge.

A gear is a wheel with teeth located on its outer edges. When gears are rolled against themselves (i.e., their outside edges intertwining), they create motion for accomplishing tasks. Examples include bicycle chains and clocks. Gears need a force to start the rotation. Larger gears with more teeth can handle more work and more difficult tasks than smaller gears with fewer teeth.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. When you observe students at work, you can visually assess their learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. Can gears create motion all by themselves? Explain.
2. What do gears do? Explain.
3. Can you think of machines that use gears? Describe two.

Observation: Organize students into science buddy teams. Observe them as they explain how gears operate and demonstrate how they work to their buddies. Observe how students solved problems that came up.

Journal assignment: What is a gear and how does it work?

Extension activities

- ✸ Organize students in groups of 2 or 3 each to count the number of rotations needed to make the trap fall.
  - a. Each group should record on a data sheet the number of gears used and the number of rotations it took to cause the trap to fall. A drawing of their best (most successful) arrangement can also be included. Or circles can be cut out and glued on the paper to illustrate the gear design.
  - b. Have each group demonstrate for the class their best gear design.
  - c. During the demonstration, have the class count the number of rotations needed and record the data on a class chart.
  - d. Conduct a class discussion with the following questions:
    - "How did your group go about deciding how to arrange the gears?"
    - "What problems did your group have in making your trap fall?"
    - "What would happen if smaller gears were used? Larger gears?"
  - e. Experiment with smaller and larger gears, either in groups or as a class demonstration.

- Arrange for students to study a bike. Help them observe how its gears work. Facilitate a discussion of their observations with questions like:
  - "Are all gears in a bike the same size?"
  - "What work do gears perform for the bike?"
  - "What power source activates the gears?"
  - "What happens when that power source is stronger or weaker?"
- Have a group of students assemble the Mousetrap® Game. Have other groups track the marble as it travels through the course and finally drops into the trap.

Subject integration

Social Studies. Arrange for a field trip to a factory or your local vocational school so that students can observe how gears are used in machinery. Include a post-visit discussion about how gears help the factory produce an end product that we all use.

Resources for teachers

Experiments With Motion by R. Gardner. (Enslow Publishers, Inc., 1995.)

Resources for students

First Science: Make It Move! by J. Rowe and M. Perham. (Children's Press, 1993.)

Trapping Bears Data Sheet

Name(s): ____________________

Trial	Number of Gears	Number of Rotations Required to Trap the Bear
1		
2		
3		
4		

Draw your best bear trap below or on the back of this sheet.

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WHAT'S GOING ON IN THERE?

Topic: Disassembling and reassembling machines

Learning objectives

Students will:

1. Disassemble some simple machines to study how they work.
2. Increase their skills with hand tools through practice.
3. Gather increased knowledge of the functioning of everyday machines through exploration.

Process skills

● Building models
○ Categorizing or classifying
● Communicating
● Comparing
○ Controlling variables
○ Experimenting
○ Hypothesizing
○ Inferring
○ Interpreting data
○ Measuring
● Observing
● Ordering
○ Predicting
● Recognizing relationships
○ Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
○ 3
○ 4
● 5
● 6
○ 7
○ 8
● 9
● 10
○ 11
● 12

Refer to Appendix F, p. 253, for a description of outcomes.

Estimated time

Setup .... 10 minutes
Exploration 45 minutes over several days
Cleanup ...... 10 minutes

Key science principles

- Machines extend human ability
- Machines contain moving parts

Materials

Food (e.g., carrots, shelled peanuts)

Manual food grinders

Plates

Small needle-nose pliers

Phillips and flat-head screwdrivers

Box for tools

Parents may be willing to loan some or all of the tools and food grinders. Send home a note describing the experiment, learning desired, and tools needed. Some parents have even volunteered to team teach such learning activities, so don't hesitate to invite their participation, as well!

Safety tips

- Choose machines with the lowest risk for injury.
- Watch for sharp parts and cover them with electrical tape, if possible.
- Monitor students' use of tools to avoid injuries. For example, a screwdriver can poke, cut, or stab.
- If an electrical machine is used, cut off plugs so they cannot be inserted into wall sockets.
- Consider the amount of materials and make sure work areas contain enough space to work safely.
- Consider how many students can safely use the disassembly center/work area at one time and for how long. *Hint: Use a sign-up sheet or token management system to monitor center traffic.*
- Conduct a safety seminar in preparation for this learning activity. (See the first engagement activity.)

Engagement activity

1. Conduct a safety orientation immediately prior to the exploration activity. Use as much interactive learning as possible to ensure that students assimilate the learning. Here are some safety ground rules to teach students in preparation for disassembling machines:
    - Use one tool at a time.
    - Keep all tools and machines in the disassembly center/work area.
    - Tools and machines should remain **on the table** when not in use.
    - Stand and/or walk with a tool **only when absolutely necessary** to complete a task.
    - **Walk slowly** with tools and machines. NO RUNNING.
    - Use **work gloves** whenever you handle sharp machine parts or tools.
    - Store all parts appropriately, if they are not reassembled.

    You may wish to divide students into teams of 2-4 and instruct each team to create a sign or poster for each ground rule. Post the signs in the work area as reminders.
2. Begin a class discussion with the introduction of a manual food grinder. Ask students if they have ever seen one. If someone responds "yes," ask the student to explain what it does. If none of the students are familiar with a food grinder, help them guess what it might do. Next, have a student grind some food for the class. Be sure all students can see. If necessary, let them come to the work area in groups large enough to surround the table to observe the food grinding. Close the exercise by explaining to students that everyone will have a chance to use a grinder. *Help younger students to examine how machines work by using the book and/or CD-ROM, The Way Things Work, by David Macaulay.*

Exploration activity

Day 1

1. Arrange several food grinders at tables to allow groups of 2-3 students to grind carrots and nuts. *Hint: These will be saved and eaten later, so wash the carrots!* Be sure each student has an opportunity to experience the grinding process.
2. After all students have had a chance to grind some food, allow the groups to eat what they have ground. Hint: Carrots can be mixed with raisins; ground nuts can be spread on crackers like peanut butter. (Food alternative: Let groups throw a tea party to celebrate their grinding experiences. Substitute bologna salad ingredients for carrots or peanuts to make tea sandwiches.)
3. Discuss the following:
    - "What did the food look like before it went through the grinder?"
    - "What did it look like after it went through the grinder?"
    - "What does the grinder do?"
    - "How does it happen?"
    - "What is going on in there?"

    As students discuss their thoughts, make clarifying statements to summarize what they are communicating such as "You're saying that . . ."

After Day 1

1. Create several "disassembly" centers. Include a food grinder and tools in each center.
2. Let individuals or pairs of students use the tools provided to disassemble the grinders. *Students may require adult supervision for this step.*

3. Wash and dry the pieces. *Hint: Use a dual-sided bucket for cleaning so you can move from one work area to the next. Put soapy water in one side and rinse water in the other. After rinsing, lay the parts on the dish towel, wrap them in it and quickly pat dry, then open the towel for air drying. Parts should finish drying in approximately 5 minutes.*
4. Challenge students to reassemble the grinders. (Note: The reassembly process will take time; therefore, you may wish to rotate students through the centers as one task in a series of individual or small-group learning tasks, perhaps extending the learning over several days.)

   Provide support and encouragement to students as they work by asking questions such as:

   - "How does this part help the machine work?"
   - "How did you figure out what this part does?"
   - "What would happen if you put the parts of the machine together in a different way? Why don't you try that?"
   - "What would happen if you did not use [this part] in the machine?"

   Expect that some students will struggle more than others with reassembling the grinder. Encourage them, but let them reassemble the grinder **for themselves**. It is **very important** to the students' learning process and their confidence with scientific activities that you avoid the temptation to reassemble the grinder for them. If frustration sets in or they run out of ideas, ask questions like, "What will happen if you....?," and help them identify new options to try. It may also be appropriate to suggest that a student observe how one or more classmates is performing their task. *Note: This might be a more difficult activity for students who have not been given opportunities to manipulate* *materials and use tools—especially girls. Be sure to give these students plenty of encouragement and support. (Refer to Appendix D, pp. 329-334, for additional instructional strategies concerning gender equity.)*

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge.

A grinder is a simple machine that extends human ability. It performs the work of grinding larger pieces of food into very small pieces and/or a creamy substance, like peanut butter. As the grinder handle turns, it pushes the spiral core against the food and the food against the graters or grinders. They are sharp so they cut the food into small pieces. The pressure (pushing) causes the food to push through the grinder holes and out the other side.

The food grinder makes an excellent learning machine because it contains only a few, relatively large parts. Thus, the grinder addresses safety concerns, as well as limitations in small muscle coordination and problem-solving skills, that are encountered when working with younger students. In addition, grinders are sturdy and last a long time. Parents may donate grinders for the lesson or you can purchase them at thrift stores.

NOTE: This lesson offers more student development than its learning objectives suggest, including problem-solving skills, visual-spatial skills and small motor coordination. In addition, the excitement of tearing down and rebuilding a machine successfully fosters both general and scientific confidence. Such activities also encourage a love of tinkering.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. When you observe students, you can assess their learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. What does a food grinder do?
2. How does it work?
3. List some of the parts of a food grinder.
4. What does a ____________ do in the machine? (Insert name of grinder part.)

Hint: Use these questions with other machines explored by students, too. Simply insert the name of the machine for "food grinder."

Observation: Monitor students as they reassemble their machines. Record the number of trys necessary to bring the machine back to working condition. Track their progress with each practice opportunity (e.g., same or different machines). If any student is not using fewer trys to reassemble succeeding machines, assess the root problem and provide intervention.

Journal assignment: What did you do to reassemble your machine? How did you feel as you worked on it?

Extension activities

- *Machine Charades.* Divide students into groups of 4-5. Give each a "mystery bag" (e.g., a brown paper bag containing a machine, such as a can opener, stapler, pencil sharpener, deodorant bottle, mist sprayer, or paper cup dispenser). Provide a private area for each group to open their bag and study the contents. Then instruct each group to act like the machine when it is working. Explain that each group member will act like one part in the machine and, together, the group will demonstrate the machine in operation. The other groups will guess the machine.
- Allow students to bring in mechanical toys with moving parts. Divide students into groups of 3-4; give each group a toy. Let groups play with one of the toys for about 15 minutes, then ask them to discuss within their group how the toy works. Provide paper and pencil for drawing ideas. Circulate, helping groups discuss and modify their ideas. Use questions like:
  - "What do you think about that?"
  - "Do you agree?"
  - "Do you all agree on how it works? If not, could there be a combination of two ideas involved?"

  Groups may explain to the class their ideas about how the toy works. (Note: Be sure to explain to students that toys may not be disassembled or destroyed for this exercise.)

Resources for teachers

What Will Happen If? by Barbara Sprung et al. (Educational Equity Concepts. 1985.)

Projects with Machines by John Williams. (Gareth-Stevens.)

Resources for students

Simple Machines by Anne Horvatic. (E.P. Dalton.)

Toy Box Science Series: Gears by Chris Ollerenshaw. (Gareth Stevens.)

Toy Box Science Series: Levers by Chris Ollerenshaw. (Gareth Stevens.)

Toy Box Science Series: Wind-ups by Chris Ollerenshaw. (Gareth Stevens.)

Toy Box Science Series: Gears by Chris Ollerenshaw. (Gareth Stevens.)

What's Inside Everyday Machines? by _________. (Dorling Kindersly.)

Power Machines by Ken Robbins. (Henry Holt.)

The Way Things Work by David Macauley. (Book and CD-ROM)

Notes

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WACKY INVENTIONS

Topic: In this culminating activity, students will see how machines work together

Learning objectives

Students will:

1. Study the detailed workings of mechanical devices.
2. Combine the functions of several very different devices to create a machine that performs a totally new function.

Hint: This activity requires prior experience with machines. Students should have completed several other machine exercises, including "What's Going on in There?" prior to completing this learning activity.

Process skills

● Building models
○ Categorizing or classifying
● Communicating
○ Comparing
○ Controlling variables
● Experimenting
○ Hypothesizing
○ Inferring
○ Interpreting data
○ Measuring
○ Observing
○ Ordering
● Predicting
● Recognizing relationships
○ Recording

Ohio 4th-grade science proficiency outcomes

○ 1
● 2
○ 3
○ 4
● 5
● 6
○ 7
○ 8
○ 9
● 10
○ 11
● 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup .... 10 minutes
Exploration ... 45 minutes, minimum. Students may need more time or a second day.
Cleanup ...... 10 minutes

Key science principles

- Machines extend human ability
- Simple machines work together to make more complex machines

Materials

Supply these items in a location that is accessible by all students:

Glues (Elmer's or wood)

Tape (masking and scotch)

Scissors

Staplers

Extra staples

Create a student's choice collection from items listed below (not all are necessary). Display it in a separate location. The separate locations reduce congestion and safety hazards.

- Straws
- Plain paper
- Cardboard
- Paint stirrers
- Egg cartons
- Empty boxes
- Empty thread spools
- Nails
- Potato slices
- Toothpicks
- Plastic/metal pipes
- Blocks
- Plastic bottles
- Magnets
- Paper clips
- Paper sacks
- Plastic bag fasteners
- Shoelaces
- Unsharpened pencils
- Milk cartons/jugs
- 35mm film cans
- Tinker toys
- Craft/popsicle sticks
- Rubber bands
- Parts from old machines
- Packaging materials
- Old panty hose/nylons
- Various sizes of washers
- Paper plates
- Tin cans w/filed edges
- Thin metal coat hangers
- Miniature marshmallows
- Fishing line
- Buttons
- Feathers
- Modeling clay

Yarn and string
Dry spaghetti
Gumdrops
Plastic lids
Plywood
Spring-style clothes pins
Beads
Paper towel rolls
Toilet paper rolls
Other small wood pieces

Note: You and your students can include "junk" of your own, as well as any other materials that have been used to construct simple machines in previous learning activities.

Safety tips

- File the tin cans or other metal objects to eliminate sharp edges.
- Lightly sand wood pieces if splintered.

Engagement activity

Read the following poem by Alan J. McCormack (Learning Magazine, January, 1976) to or with students. Then explain that they will be making "Thingamajigs!"

Thingamajig
What on earth is a thingamajig?
Small and blue? Red and big?
Can you use it on Mondays to brush your teeth?
Is it made of cardboard with springs underneath? . . .
A tiny contraption to catch a gray mouse
Or an elephant scrubber as big as a house.
Make it from any old junk that you find;
a thingamajig grows in your mind!

Exploration activity

1. Have students work individually or in pairs. Show them the general items and student's choice areas, explaining their purposes.
2. Challenge students to combine any number of the materials available in the student's choice area to create a something—anything!— (i.e., a "thingamajig"). The **only** rule for this exercise is that the object must **do** something. Explain that it could help students complete a task or simply entertain.
3. To help students get started, encourage them to use what they have learned about machines and simple machines from previous learning activities to create their own thingamajig. *Hint: The teacher's role is to help students decide how they will combine materials to create their thingamajigs. It may be helpful to have students draw their inventions before building them. In addition, you may want to ask students to name their inventions.*
4. While students are developing thingamajig ideas, circulate and ask questions of anyone who appears to be struggling. Sample questions include:
    - What are current uses for the items you've chosen?
    - What can they do?
    - How do they work?
    - What will happen if you combine the uses of these items?
    - What could you call it now? For example, a "refrigerator stuffer" could be created from a clothespin, a large magnet and a small tin juice can. Glue the magnet to the clothespin, which is clipped to one side of the can. Hang this invention on a refrigerator to hold loose items like pocket change, pins, paper and clips.
5. Have students demonstrate their inventions for classmates.

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Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge.

This creative activity encourages students to "think inventive," which is a skill required when pondering applied mechanics problems in the real world. It is important for students to learn that such thinking skills are sought in the work world. In addition, students need to understand that new mechanical inventions are rarely entirely new. They are often combinations of objects that already exist. *Note: There are many library books on the topic of inventions, some of which are provided in the Resource list of Appendix B, pp. 295-307. These books provide a wide range of examples of inventions that have significantly affected our society.* This learning activity fosters investigative skills (for examining the workings of mechanical devices), problem-solving skills, and creativity (to identify ways to combine the functions of several very different devices to create a machine that performs a totally new function).

Evaluation

Questions like those listed below can be used for testing, homework assignments, and similar evaluation techniques. Observation allows you to visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. What is a "thingamajig?"
2. Our "thingamajigs" had to **do** something. Why? (Answer: Because they are machines.)

Observation: Check students' inventions and monitor their presentations in order to answer the questions listed below. Record your assessments.

- Does the finished product (thingamajig) show an increased understanding of the workings of mechanical devices?
- Have the students combined the functions of several very different devices so they perform a new function together?
- Can students verbally discuss the invention's make-up and function?

Journal assignment: Look around you and find an invention that you like. Identify it by name, then describe **how** it works and **what it does** for you!

Extension activities

- Ask students to go on a thingamajig hunt. With adult supervision, have them visit old attics, flea markets, antique stores, basements, garages, and similar places to find unusual mechanical devices. Ask students to bring in their items to share with the class. If items cannot be brought to class, have students bring photographs or drawings of their objects instead. In some cases, an object's purpose may not be known. No problem! Help students try to figure out the object's *intended* use.
- Mix a bubble solution of Dawn dish washing detergent and a small amount of water in a 9" x 12" cake pan. Place on a counter or desk: a rubber canning jar ring, a drinking straw, a funnel, a traditional bubble wand, a rubber band, a toilet paper roll, a piece of paper (8" x 11"), a 12-inch piece of

string, a paper cup, and a plastic margarine container lid. Have scissors available. Let students experiment to see what materials will make bubbles. Ask them to try each item separately first. Then let them combine two or more items to create a bubble-blowing contraption. If students do not eventually recognize that all of the items can become a bubble-blowing machine, ask them the following questions:

- What is the same about all of the objects that make a bubble?
- What could we do to the "non-working" object to make it more like the other bubble-blowing objects?

Subject integration

Art. Use the student's choice collection of materials to create a collage or a sculpture for a class project.

Language Arts. Have students write about their thingamajig. They can feature it in a fiction story or poem, or detail its uses in an advertisement.

Social Studies. Read about the lives of Thomas Edison, Ben Franklin, and other inventors. Remember to **include minority and women inventors** in this assignment. For example, Lillian Evelyn Moller Galbreth developed new methods for physically disabled people to accomplish everyday tasks; Bette Nesmith Graham invented a product for making corrections on typewritten material that was later marketed as Liquid Paper™. Furthermore, some of the inventions made by children are also noteworthy.

Resources for teachers

Bubble Festival by Jacqueline Barber and Carolyn Willard. (GEMS Series, Lawrence Hall of Science, 1994.)

Inventors Workshop by Alan J. McCormack. (Fearon Teacher Aids, 1981.)

Mothers of Invention: From the Bra to the Bomb, Forgotten Women and Their Unforgettable Ideas by Ethlie Ann Vare and Greg Placek. (William Morrow & Co., 1988.)

Simple Machines by Girls Incorporated (formerly Girls Clubs of America), Operation SMART series. (Girls Inc., 1993.)

Resources for students

Readers Science Series: Pulleys by Michael Dahl. (Bridgestone Books.)

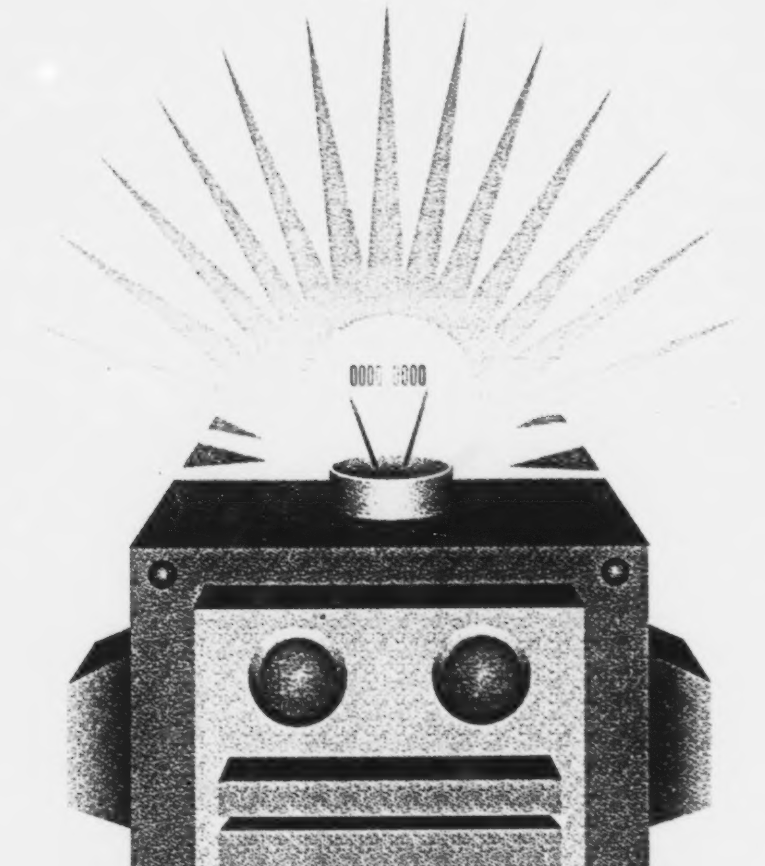
Readers Science Series: Levers by Michael Dahl. (Bridgestone Books.)

Readers Science Series: Tractors by Michael Dahl. (Bridgestone Books.)

Readers Science Series: Inclined Planes by Michael Dahl. (Bridgestone Books.)

Readers Science Series: Wheels and Axles by Michael Dahl. (Bridgestone Books.)

NOTE: Readers Science Series *books can only be ordered directly from the publisher.*



FUN WITH PHYSICS:

Real-Life Problem Solving for Grades K-3

Exploring Electricity

Learning Activities **Page**

Power or Not? 121

Go with the Flow 129

Light Bright 135

All Charged Up and Ready to Move 147

Attractions 153

Walter the Waltzing Worm 161

NOTE: Teachers may want to treat the learning activities in this section as a unit. They may also wish to supplement these learning activities with those described in the teacher resources listed in each section. The learning activities in Exploring Electricity give young learners an overview electricity. The first two activities are about electrical power sources and flow. In "Light Bright," students discover how batteries and bulbs work. "All Charged Up and Ready to Go" helps students explore concepts related to static electricity. In "Attractions" and "Walter the Waltzing Worm," students explore magnets and magnetic attraction.

ELECTRICITY VOCABULARY

Battery

Bulb

Circuit

Electromagnet

Light

Magnet

Magnetic attraction

Negative

Positive

Wire

Safety tip

- Post safety rules when conducting the learning activities in Exploring Electricity.

POWER OR NOT?

Topic: Sources of electrical power

Learning objective

Students will identify items powered by electricity through an electrical cord or a battery.

Process skills

- ○ Building models
- ● Categorizing or classifying
- ● Communicating
- ○ Comparing
- ○ Controlling variables
- ○ Experimenting
- ○ Hypothesizing
- ○ Inferring
- ○ Interpreting data
- ○ Measuring
- ● Observing
- ○ Ordering
- ○ Predicting
- ○ Recognizing relationships
- ● Recording

Ohio 4th-grade science proficiency outcomes

- ● 1
- ● 2
- ○ 3
- ● 4
- ○ 5
- ○ 6
- ● 7
- ○ 8
- ● 9
- ○ 10
- ○ 11
- ○ 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup..................... 5 minutes

Exploration...........20 minutes

Cleanup................. 5 minutes

Key science principles

- Electrical safety
- Electrical current
- Electricity conversion
- AC/DC
- Voltage

Materials

Radio (or other appliance) that uses both a cord and battery

Electrical cord

Batteries (different sizes)

Safety plug for electrical outlet

Markers

Newsprint

Power or Not? data sheet

Safety tips

- Make sure demonstration appliances are unplugged.
- Stress to students the importance of adult supervision when handling electrical devices.
- Conduct a mini-workshop regarding electrical plug/outlet safety. (See the first engagement activity.)

Engagement activities

1. Conduct a mini-workshop for students about electrical plug/outlet safety. Demonstrate an electrical outlet safety plug, explain its purpose (to prevent items from being inserted into an outlet), and pass it around for students to examine. Finally, demonstrate the safe way to plug/unplug an electrical cord.
2. Help students understand that there are two kinds of power: **alternating current** (e.g., from electrical plugs) and **direct current** (e.g., from batteries)
    a. Show students a radio (e.g., a model that can be powered by either electricity or batteries).
    b. Show students that the radio is unplugged and ask them to predict whether the radio will work.

c. Then turn on the radio. *(Hint: It will work on battery power.)*

d. Ask students to explain why the radio worked, even though it wasn't plugged in. If none of the students suggests batteries, turn the radio so the battery cover shows. Without speaking, remove the cover. See if students can identify the power source now.

e. Complete the demonstration with the conclusion, "Electricity comes from both wall sockets and batteries."

Exploration activity

1. Hold up an electrical cord for students and ask, "What is this?"
2. After someone names the electrical cord, hold up a battery and ask, "What is this?"
3. After a student identifies the battery, conduct a class discussion with the following questions:
    - "How are the battery and cord different?"
    - "Are these the only kinds of cords and batteries?" Encourage students to think about the devices they have seen at school and home. Display a few different kinds of each as the discussion progresses.
    - "Why are there different kinds of cords and batteries?"
4. Have students think of the various equipment they have at school or at home that uses electricity. Complete a data sheet to categorize the examples discussed (i.e., battery, cord, both). See the Power or Not? data sheet on p. 127.

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge or teach the concepts through enhancement, exploration or expansion activities.

Students will begin to realize that certain items require electricity in order to function. They will also identify different sources of electricity and safety issues related to electricity (e.g., outlet plug covers, handling an electrical cord).

In addition, students will realize that there are two types of power sources: **alternating current**, (i.e., the power that comes from electrical outlets and is accessed through electrical cords and plugs) and **direct current** (i.e., the power that is supplied from batteries). Home appliances, computers, and clocks are examples of machines that are powered by alternating current. Cars, flashlights, and some radios (in general) are examples of machines that are powered by direct current.

Evaluation

Questions like those that follow can be used for testing, homework assignments, and similar evaluation techniques. Observation allows you to visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their drawings and narratives.

Sample questions:

1. Which power source would you expect to find in a large television—a battery or an electrical cord?
2. Which helps a car to start, a battery or an electric cord?
3. Explain why we need different types of cords and batteries. Name and describe a few in your answer.

Observation: The third extension activity below can be used as a performance assessment.

Journal assignment: Explain why you should **never** put anything except an electrical plug into an electrical outlet.

Extension activities

- Have students graph their findings on the "Power or Not" data sheet, according to size or amount of electricity—least to most—they think the item requires.
- Cut open different types of wires and let students observe and explore the internal contents.
- Give students the exploration activity as a homework assignment. Have them share their findings the next day, adding to lists already started in class.

Subject integration

Social Studies and **Language Arts**. Have students study Ben Franklin and the discovery of electricity, then tell and/or write a story about what they learned.

Social Studies and **Language Arts**. Have students study Thomas Edison and the invention of the light bulb, then tell and/or write a story about what they learned.

Language Arts. Read, or have students read, and discuss a picture-book story that involves electricity or its invention.

Resources for teachers and students

Steven Caney's Invention Book by Steven Caney. (Workman Publishing, 1985.)

Power or Not? Data Sheet

Name(s) ______________________________

List or draw at least 6 things in your environment that need electricity to operate. Put them in the correct column.

Uses an Electrical Cord	Uses Batteries	Uses Both a Cord and Batteries

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Notes

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GO WITH THE FLOW

Topic: Flow and pressure are factors in electrical currents

Learning objectives

Students will:

1. Experience flow and pressure of a substance.
2. Use the flow and pressure experience to identify how flow and pressure work in electricity.

Process skills

○ Building models
○ Categorizing or classifying
● Communicating
● Comparing
○ Controlling variables
● Experimenting
○ Hypothesizing
● Inferring
● Interpreting data
○ Measuring
● Observing
○ Ordering
● Predicting
● Recognizing relationships
○ Recording

Ohio 4th-grade science proficiency outcomes

○ 1
○ 2
● 3
○ 4
● 5
○ 6
● 7
● 8
○ 9
○ 10
● 11
○ 12

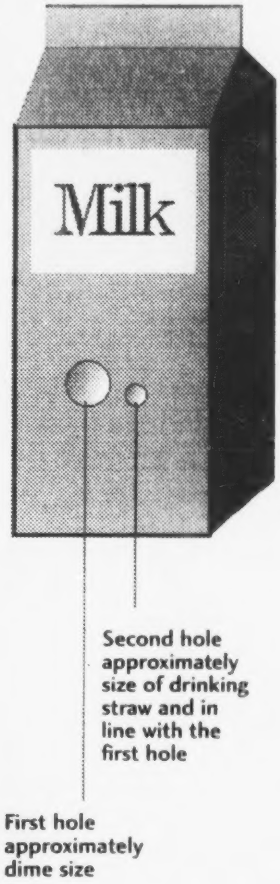
Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup	5 minutes
Exploration.	15 minutes
Cleanup	3 minutes

Key science principles

- The flow of electricity is similar to the flow of water.
- Pressure is controlled by its source.


Milk
Second hole approximately size of drinking straw and in line with the first hole
First hole approximately dime size

Materials

Milk carton with two holes (See the diagram for cutting instructions.)

Sink

Water

Masking tape

Flip chart paper

Large appliance that takes larger batteries (e.g., portable stereo)

Small appliance that takes smaller batteries (e.g., beeper, wrist watch, or cell phone)

Safety tips

- Talk with students about safety with electricity. (See the first engagement activity.)
- Conduct the exploration activity over a sink or outdoors with a hose so the water can drain, avoiding slips and other water hazards.

Engagement activities

1. Conduct a discussion with students about safety with electricity. Include these points: electricity "lives" in wall outlets and light sockets; it is very dangerous, so never play with plugs, switches, power outlets or electrical machines. Also explain that because real electricity can be dangerous, the class will pretend that water is electricity during the exploration activity.
2. Ask students what items they think require more electricity than others. Discuss and record these items on a piece of flip chart paper under the headings "More Electricity" and "Less Electricity."

Exploration activity

1. Tell students that they must use their imaginations and pretend that the water you will use is electricity.
2. Show students the milk carton. Point out the holes in it. Ask them to predict what will happen if you fill the bucket with electricity (water). (Answer: It will come out of the holes.) Encourage them to talk about which hole they think will have more electricity (water) flowing from it.
3. Cover the holes with masking tape to stop the flow of water while you fill the carton with water. Remember to fill it over a sink or bucket.
4. Remove the tape and have the class observe what happens. (Answer: The bigger hole will have a larger flow.)
5. Ask students:
   - "Which had more flow?" (Answer: the larger hole)
   - "Why did it have more flow?" (Answer: more space for the "electricity" to flow)
6. Relate this activity to the flow of electricity by examining the electrical needs of small and large appliances. While displaying one of each, ask students, "Which do you think needs more electricity to run?" (Answer: the larger appliance)
7. Explain that the larger appliance requires more electricity flowing into it (i.e., it needs a "larger hole") to work. Show students the small appliance and discuss how this appliance doesn't need as much electrical flow to run.
8. Finally, demonstrate the size and number of batteries needed to run each appliance.

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next two paragraphs will emerge or teach the concepts through enhancement, exploration or expansion activities.

Electricity flows through wires in the same way that water flows through a hose. We call this flow an **electric current**. *The flow of electricity depends on the resistance through which the current travels.* In the exploration activity, resistance is represented by the size of the holes in the milk carton. Students can visualize the concept of flow by observing that different amounts of water flow from the two different holes—more from the larger one and less from the smaller one. The water flowing out of the larger hole has **less resistance** than the water flowing out of the smaller hole.

The pressure (or force) of electricity is controlled by **voltage**—the amount of electricity available. In the exploration activity, voltage is signified by the water in the milk carton. *As long as there is enough pressure (i.e., water in the carton), there will be a current.*

Additional information about electricity is provided in appendix C, pp. 315-327.

Evaluation

Questions like those that follow can be used for testing, homework assignments, and similar evaluation techniques. When you observe students, you to visually assess their learning. Assign and review journal entries to evaluate students' learning comprehension through their drawings and narratives.

Sample questions:

1. Which requires more voltage (pressure), a boom box or a beeper?
2. Which requires a greater flow of electric current, a boom box or a beeper?
3. Name two things in the classroom that require lots of current and voltage. Name two things that need very little.

Observation: Display the chart created in the engagement activity. Have students self-check their earlier predictions, correct any errors, and add more items to the list.

Journal assignment: Explain one thing you learned about electricity today that you didn't already know.

Extension activities

- Examine flow and resistance by studying a water faucet.
    1. Have students gather around a water faucet.
    2. Turn the faucet just enough for a small stream to flow.
    3. Explain that although there is a great deal of water behind the faucet, opening it only a little results in a small flow.
    4. Then have a student hold his/her hands under the small stream.

5. Suggest that students test the theory. Challenge them with the comment, "If lots of water is available and the flow is determined by how far you open the faucet, then open the faucet all the way and see if you get a larger flow." Have a student quickly open the water faucet to full capacity while holding his/her other hand under the water. What happens? (Answer: A big splash with lots of pressure behind it. The pressure may force the student's hand down.)
6. Help students conclude that the force (or pressure) is different depending on the flow of the water. Then correlate this knowledge about flow and resistance to electric current and voltage: electricity can involve lots of flow with little pressure, little flow with lots of pressure, or lots of flow with lots of pressure.

✱ Using a hose, have students try to move objects of various sizes, shapes, and weights such as a brick, block, cup, and balloon.

1. First, open the hose for a light flow and have a student try to move the different objects with the water.
2. Next, open to a full flow and have another student try to move the objects.
3. Help students discuss why some objects moved with a light flow while others required more. Again, correlate this activity to the flow of electricity.

Resources for teachers

The Science Book of Electricity by Neil Ardley. (Gulliver Books, 1991.)
Power Up by Sandra Markle. (Atheneum, 1989.)

LIGHT BRIGHT

Topic: Batteries and light bulbs

Learning objectives

Students will:

1. Use a battery and wires to light a bulb.
2. Explain how this experiment works.

Process skills

● Building models
○ Categorizing or classifying
● Communicating
● Comparing
● Controlling variables
● Experimenting
● Hypothesizing
● Inferring
● Interpreting data
○ Measuring
● Observing
○ Ordering
● Predicting
● Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

○ 1
● 2
○ 3
● 4
● 5
○ 6
● 7
● 8
● 9
○ 10
○ 11
● 12

Refer to Appendix F, p. 353, for a description of outcomes.

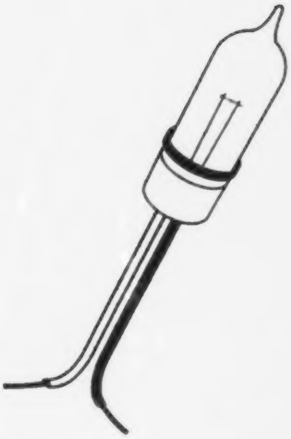
Estimated time

Setup . . . . 10 minutes
Exploration . . . 45 minutes
Cleanup . . . . . . 10 minutes

Teacher preparation time:
1-2 hours

Key science principles

- Electricity
- Circuit



Materials

Prepare a zip-style sandwich bag for each student containing:

- 1 D battery (1.5 volt)
- 1 flashlight bulb (1.5 volt)
- 2 8-inch pieces of coated copper wire (Strip ½-inch of plastic insulation from each end of the wires.)
- bulb holder (optional)

Several 2-inch strips of masking and/or electrical tape
(Hint: Tearing/cutting tape and sticking it to the side of the supplies table **before** *starting the exercise reduces commotion and delays.)*

Miniature Christmas tree light with 2 wires attached (To do this, use a full strip of Christmas tree lights. With a wire cutter, cut the wire half-way between each light. Then strip ½ inch of plastic insulation from each end of the wires.) **Important:** *Don't distribute these until later.*

Note: Teachers who are unable to secure these materials may wish to modify the activity so that only Christmas tree lights are used. Also, parents can be asked to donate materials such as batteries.

Safety tips

- Do not put more than 4 batteries together. The heat generated could cause a small explosion, resulting in burns and other hazards.
- Do not puncture batteries. Punctured batteries can explode and/or leak acid, resulting in burns and other hazards. Acid is especially dangerous to skin and eyes.
- Check batteries carefully for signs of acid leaks, i.e., rust-colored deposits on the top or bottom of a battery. Dispose of such batteries immediately and properly.

- **Never attach** any of the items used in this exercise **to an electrical outlet**. Household electricity is very dangerous.
  Hint: Instruct students to ask their parents to show them how to use electrical outlets, cords, and appliances properly. Have them discuss what they learned in order to reinforce the learning.
- Water and electrical current are a very dangerous combination. Make sure students' hands are dry before conducting these learning activities.
- Always insert a device (bulb, buzzer, motor) into the circuit. Connecting wire only to the battery will cause the wire to overheat—called a **short circuit**.

Hint: You may wish to review these safety tips with students prior to starting the exercise and/or post them as reminders. You could also use them to create a learning activity.

Engagement activity

Have the students stand in a circle with you and spread out so everyone is standing one arm's length apart. Have everyone join hands. Explain that you will squeeze Jim's hand (Jim is standing next to teacher), then Jim will squeeze Amy's hand, and so on until the "squeeze" returns to the teacher. Repeat this process until the signal returns to the teacher a second time. Without explanation, begin a third "squeeze" round, but lead Jim away from the circle **after** he squeezes Amy's hand. Direct the other students to "continue squeezing and don't move." (The latter instruction keeps the students who were standing beside you and Jim from closing the circle.) When the "squeeze" reaches the open spot in the circle, begin a class discussion with, "What happened when the 'squeeze' got to the place where Jim and I were standing?" Cover the concepts of the circle, a broken circle, and fixing the circle. Then introduce the word "circuit" and compare it to "circle." Help students define circuit in the context of their study of electricity.

Exploration activity

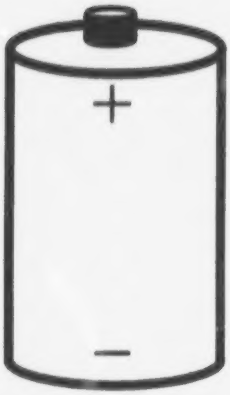
Hint: During this activity, students are encouraged to discover different ways to light the flashlight and Christmas tree bulbs. For maximum learning, the teacher should provide **minimal** *structure.*

1. Distribute a sandwich bag of materials to each student.
2. Instruct students to use the battery and wires found in the bag to light the flashlight bulb.
3. Explain that they may use pieces of tape to hold things in place, if desired.
4. Challenge them with, "See how many different ways you can light the bulb."
5. Give students **no further instructions.**
6. Circulate around the room. Ask open-ended questions and make open-ended statements to enhance the learning. Samples include:
    - "Tina has lit her bulb in a different way."
    - "Your bulb isn't lighting. What could be the problem?" "What else could you try?" (Possible answers: The wires are not in the right place, they're not connected tightly enough to the battery or bulb, and one of the wires is broken.)
    - (You notice that Robert is having trouble lighting his bulb. Sarah is seated next to him.) "Sarah, will you show Jim how your bulb lights?" (You hope that Robert watches—or encourage him to watch.)
    - "How could you light your flashlight bulb using just one wire?" (See answers in the evaluation section of this learning activity.)

7. As you notice the students successfully lighting their bulbs, begin distributing the Christmas tree lights. Give no instructions—just encourage them to find out what they can discover about lighting the bulb.
8. Give students time to explore, then ask them to explain how they were able to light their tree lights.
9. Continue exploration and discovery as a class, asking two students, "How could the two of you combine your materials and still make all of the bulbs light?" Give them no other instructions. While the two students experiment, allow the other students to either continue exploring or find a buddy and conduct the same experiment. (Answers: They could twist all wires together in a line and could tape 2 batteries together end to end—a positive end touching a negative end.)
10. Let the two students demonstrate the results of their experiment to the class. Then ask, "What happened to the light when you did that?" "Can you explain why?" (Answer: It became brighter because more power was going through the circuit.)
11. Continue the discussion, focusing on the electrical concepts involved. Use questions like:
    - "How was our 'squeeze' circle like the circuit we made with the battery, bulb, and wires?"
    - "Consider all the configurations that lit the bulbs. What things did they have in common?" (Answers: There was an unbroken circle of electricity—a circuit—that flowed from one end of the battery, through the wires, to the bulb, and back to the opposite end of the battery. Each flashlight bulb has 2 special places: one on the tip of the base and one

on the side of the base. They are both metal. Touching these places makes it light. (Note: glass does not conduct electrical current but metal does.)

- "Why can't we touch the glass of the bulb to complete the circuit?" (Answer: The glass is not part of the circle of electricity because the wires inside the bulb are not touching the glass portion of the bulb.)
- "Where does electricity enter and exit batteries?" [Answer: Each battery has 2 special places—a bump (+) end and a flat (-) end. Both battery ends must be tightly touched with wire for the bulb to light—to complete the circuit/circle of electricity. (See the illustration below for a sample method of "teaching" students about + and - terminals.)]
- "If your bulb did not light, what might have happened?" (Answers: The wires were not in the right place and/or the wires were not connected tightly enough to the battery or bulb.)
- "What other things may have kept the bulb from lighting?" (Answers: Dead battery, dead bulb, broken wire, and/or insulation not stripped from the end of the wire.)



battery terminals

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraphs will emerge or teach the concepts through enhancement, exploration or expansion activities.

In this series of explorations, the battery served as the **power source**. For a bulb to light, there must be a **complete circuit** of electricity that flows from one end of the battery, through the wires, through the bulb, and back to the other end of the battery.

- Electricity will not flow if the circuit is broken (e.g., loose connection, broken wire, dead battery, dead bulb, non-stripped wire). A broken circuit does not allow electricity to pass to the bulb, so the bulb will not light.
- On the other hand, connecting more than one battery (as in a flashlight) increases the voltage (pressure) behind the flow of electricity and the bulb burns brighter.
- Connecting more than one bulb in a line decreases the pressure reaching each bulb; therefore, the bulbs are dimmer than if only one bulb was connected.

Evaluation

Questions like those listed below can be used for testing, homework assignments, and similar evaluation techniques. When you observe students engaged in discovery activities, you can visually assess their learning. Assign and review journal entries to evaluate students' learning comprehension through their drawings and narratives.

Sample test/quiz: Give students a worksheet that features battery, bulb, and wire diagrams. You can use the worksheets provided on pages 145-146. Students should look at the diagrams and check either the "yes" or "no" column, indicating whether each diagram will light a bulb. Students can use their batteries and bulbs to "test" the diagrams. *(Answer key for 2-wire diagrams: 1 - yes, 2 - no, 3 - yes, 4 - no, 5 - no, 6 - yes. Answer key for 1-wire diagrams: 1 - no, 2 - yes, 3 - yes, 4 - no, 5 - yes, 6 - no.)*

Observation:

1. On a blackboard or chart paper, draw working diagrams suggested by students (or let students draw the diagrams).
2. Have students show someone else how to light a bulb and explain the process.
3. Have students disassemble their circuits at the end of the activity and return the battery, bulbs, and wires to the plastic bag.

Journal assignment: Use words and/or pictures to explain how wires and batteries make a light bulb work.

Extension activities

- ✱ The books listed on the following pages provide many additional activities that can extend students' knowledge of batteries and bulbs (e.g., making a flashlight, making a game board).
- ✱ Help students build a circuit quiz board using cardboard, foil, battery, two wires, and tape. Arrange for them to use it in a school-wide activity.

Subject integration

Language Arts. Either read aloud, or let students read, books pertaining to electricity, such as:

- *Discovering Electricity* by Rae Bains. (Troll Associates, 1982.)
- *Electricity* by Jason Cooper. (The Rourke Corporation, 1992.)
- *Switch On, Switch Off* by Melvin Berger. (Harper Collins, 1989.)

Language Arts. Develop a list of "electrical" spelling words, e.g., battery, bulb, circuit, light, wire, electricity. Use them for a theme spelling test or have students write a story in which they must use **all** of the words on the list.

Social Studies. Read about the lives and contributions of Franklin, Edison, Voltaire, Ohm, and Bell in books like:

- *Beakman's Book of Dead Guys and Gals of Science* by Luann Colombo. (ELP Communications, 1994.)
- *Benjamin Franklin and Electricity* by Steve Parker. (Chelsea House Publications, 1995.)

Art: Envision a new and different type of lamp. Draw a picture of it.

Resources for teachers

Electricity: The Way It Works by Neil Ardley. (Heinemann Educational Books, 1991.)

Hands On Science: The Science Series (Grades 1-2) by Robert W. Smith. (Instructional Fair, Inc., 1989.)

How Science Works by Judith Hahm. (Reader's Digest, 1991.)

Power Up by Sandra Markle. (Macmillan Publishing Co., 1989.)

The Science Book of Electricity by Neil Ardley. (Harcourt Brace Jovanovich, 1991.)

Science with Batteries by Paul Shipton. (Usborne Publishing, 1993.)

Wonder Science, a magazine for students and teachers. (American Chemical Society/American Institute of Physics, March, 1995.)

Resources for students

Discovering Electricity by Rae Bains. (Troll Associates, 1982.)

Electricity by Jason Cooper. (The Rourke Corporation, 1992.)

Switch On, Switch Off by Melvin Berger. (Harper Collins, 1989.)

Where Does Electricity Come From? (Usborne Science Activities)

Science Book of Electricity by Neil Ardley.

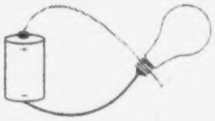
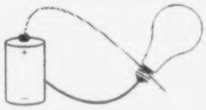
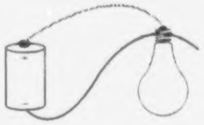
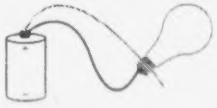
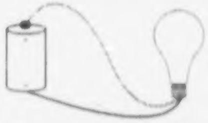
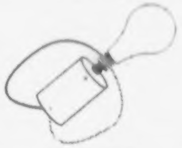
Arthur's New Power by Hoban.

Blackout by Ann Rockwell.

Light Bright Worksheet I

Name ______________________________

Predict whether or not these 2-wire circuits will light the bulb.

	yes	no
		
		
		
		
		
		

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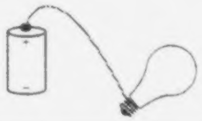
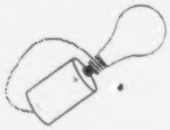
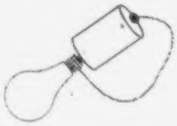
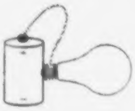
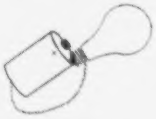
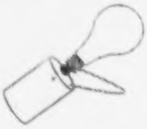
Light Bright Worksheet II

Name ____

Predict whether or not these 1-wire circuits will light the bulb.

	yes	no
		
		
		
		
		
		

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ALL CHARGED UP AND READY TO MOVE

Topic: Static electricity

Learning objective

Students will gather knowledge about attraction and repulsion forces, static electricity, and positive and negative charges.

Process skills

● Building models
○ Categorizing or classifying
● Communicating
● Comparing
○ Controlling variables
● Experimenting
○ Hypothesizing
○ Inferring
● Interpreting data
○ Measuring
● Observing
○ Ordering
● Predicting
● Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
● 3
● 4
● 5
● 6
● 7
● 8
● 9
○ 10
● 11
● 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup . . . . 10 minutes
Exploration . . . . 45 minutes
Cleanup . . . . 5 minutes

Key science principles

- Attraction and repulsion forces
- Static electricity
- Positive and negative charges

Materials

I Was All Thumbs by Bernard Waber

Balloons

Comb

Scissors

Tissue paper (variety) (Students will cut an octopus shape out of it.)

Flowing water (e.g., sink)

Safety tips

- Instruct students to use care when handling and using materials to avoid cuts and similar hazards.
- Caution students not to share balloons. They should rub **only** their own hair with their balloons to avoid health risks.

Engagement activities

Help students learn about static electricity by doing the following:

1. Give each student a new **balloon**.
2. Explain the term "charged balloon."
3. Ask them if they think that a charged balloon has enough force to move things without touching them. Survey the class and record the results on the board.
4. Then ask a student to rub a balloon against his/her hair until static electricity is produced—until the balloon becomes charged.
5. Challenge the student to use the charged balloon to move another object without directly touching it.
6. Once the student successfully demonstrates the concept, challenge the rest of the class to charge their balloons and find something in the classroom that they can move with the balloons.

7. After 5-10 minutes of exploration, discuss with the class, "Why can a charged balloon move another learner's hair without directly touching the hair?" and "Why can it move pieces of paper without directly touching them?" Also discuss why the balloons could not move other objects, like a book and a chair. Be sure to introduce the concept of static electricity during the discussions.
8. Replace the balloons in the previous engagement activity with **combs**. Have each students charge a comb by rubbing it against a clean, dry cloth.
9. Then demonstrate that when a charged comb is situated close to a thin stream of running water, the comb pulls (attracts) the water.
10. Help students test this for themselves and show them how to make the water "dance" by gently jiggling the comb.

Exploration activity

1. Read *I Was All Thumbs* by Bernard Waber. After discussing the story, have students make an octopus out of tissue paper. (Note: If this book is unavailable, substitute a book about spiders and use spiders instead of octopuses throughout this activity.)
2. Arrange the students in cooperative teams of two. Distribute balloons.
3. Pose the challenge: "Can you move your octopus's legs?" After students discover that the charged balloon (static electricity) will move the legs of their octopuses, facilitate a discussion to help them understand how static electricity works. Use questions like:
   - "How did you make the legs of the octopus move?"
   - "What did you do with the balloon?"

- "Did the distance between the balloon and the octopus make a difference in the movement?"
- "What force moved the legs of the octopus?" (Answer: static electricity)
- "How could you get the legs of the octopus to move faster?"

4. Give students more time to explore how to get the legs of the octopus to move faster. Share observations, like rubbing harder to increase the static charge.
5. Conclude the activity with a homework assignment. Have students share their discoveries with their parents and ask them or other adults to write a brief description of their experiences with static electricity. Instruct students to return their descriptions within 2-3 days. Post them on the bulletin board and let students share their experiences.

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge or teach the concepts through enhancement, exploration or expansion activities.

Moving a **charged** balloon back and forth across a paper object creates enough force to move parts of the paper. The balloon has a negative charge, but the paper has some positive charge. The attraction between the positive and negative **atoms** is strong enough to diminish the gravitational pull. Thus, the legs on the paper octopus move.

Evaluation

Questions like those listed below can be used for testing, homework assignments, and similar evaluation techniques. When you observe, you can visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their drawings and narratives.

Sample questions:

1. How do you "charge" a balloon? (Answer: Rub it back and forth against something, like hair.)
2. Is it a negative or positive charge? (Answer: negative)
3. Negative atoms attract what kind of atoms? (Answer: positive)

Observation: Observe students as they complete the exploration and/or extension activities. Assess and record whether students demonstrate an ability to use their knowledge about creating static electricity to move different objects. During discussions, assess and record whether students can explain how static electricity is created and used in the activities.

Journal assignment: Sometimes static electricity is a "bad" thing to have around (e.g., computers). Think of a situation like that and explain why static electricity is unwanted.

Extension activities

- Create a variety of cut-outs in various shapes and sizes, e.g., a butterfly, a big star, a small star. Help students experiment with a charged comb or balloon to determine whether an object's shape or size determines how easily it can be moved with static force. Have students record the results.

- Distribute magnets. Have students explore magnetic force. Facilitate a discussion or other group activity to help students compare magnetic force to static force.
- Help students test whether static electricity can travel through different materials. Put paper scraps in a 2-liter plastic bottle. Move a charged balloon up and down the bottle. Do the papers move inside the bottle?
- Help students recognize that static electricity is sometimes unwanted. Ask a computer technician to make a presentation to the class about the effects of static electricity on a computer and the devices used to eliminate static (e.g., static-free bands, static dust cloths).

Subject integration

Art. Let students play with Etch-A-Sketch® toys. Discuss how static electricity helps to make them work.

Language Arts. Have students write a "How To Make Static Electricity" story.

Resources for teachers

Teaching Physics With Toys by Taylor, Poth and Portman. (Triangle Learning Press, and Imprint of McGraw-Hill, 1995.)

How to Do Science Experiments with Children by Bentley and Hobbs.

Resources for students

Einstein Anderson Science Sleuth (It's Shocking) by Seymor Simon.

ATTRACTIONS

Topic: Magnetic attraction

Learning objective

Students will:

1. Discover principles related to magnetic attraction.

Process skills

○ Building models
● Categorizing or classifying
● Communicating
● Comparing
● Controlling variables
● Experimenting
○ Hypothesizing
○ Inferring
● Interpreting data
○ Measuring
● Observing
○ Ordering
● Predicting
○ Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
● 3
● 4
○ 5
● 6
○ 7
● 8
● 9
○ 10
○ 11
● 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup . . . . 5 minutes
Exploration . . . . . . 2 30-40 minute sessions
Cleanup . . . . 5 minutes

Key science principles

- Magnetism
- Magnetic attraction

Materials

Clear container (e.g., jar or bowl)

Salt

Iron filings

Chart paper for classroom web

Paper clips

Magnets (several types and/or sizes, e.g., bar magnets and horseshoe magnets)

Various materials—some of which are magnetic and some that are not (e.g., screws, paper clips, nails, coins, keys, marbles, glass beads, plastic toy cars or miniature figures, rubber bands, pencils, crayons, erasers, toy ball, wooden beads, small wooden blocks)

Long nails

Safety tips

- Remind students to keep all objects and substances out of their mouths.

Engagement activity

Help students begin an exploration of magnetism by doing the following:

1. Gather the following materials: salt, iron filings, a clear container (e.g., jar or bowl), and a magnet.
2. In front of the students, pour equal parts of salt and iron filings into the clear container.
3. Bring out a magnet and ask students to make predictions about what will happen when the magnet is put into the mixture.

4. Put the magnet into the mixture. (The salt will remain in the bowl and the iron filings will stick to the magnet.)
5. Ask students to try to explain what they observed. Tell them that they'll have an opportunity to learn more about magnetism when they do the exploration activities.

Exploration activities

As a class, create a "What Do We Know About Magnets" **web** on chart paper (e.g., information that answers questions such as "What are magnets?" and "How are magnets used in everyday life?"). Then do the two following exploration activities. *Hint: You can also use students' contributions to the web to assess their current knowledge about magnets.*

Exploration activity 1

Help students explore magnetism by determining which materials are attracted to magnets and which are not by doing the following:

1. Divide the class into teams of 2-4. (Optional: assign roles of recorder, reporter and materials handlers.)
2. Distribute the materials: magnets and various materials—some that are magnetic and some that are not (e.g., screws, paper clips, nails, keys, marbles, glass beads, plastic toy cars or miniature figures, wooden beads, small wooden blocks).
3. Have students do the following on their Attractions data sheet:
    a. List (or draw) the items that the team is using to explore magnetism,
    b. Predict whether or not each object will be attracted to magnets,
    c. Note which items were attracted to the magnet and which were not.

4. After students have had a chance to explore, help them discuss what they experienced and draw conclusions. Add appropriate information to the class web.

Exploration activity 2

Help students explore magnetic attraction by doing the following:

1. Divide the class into teams of 2-4. (Optional: assign roles of recorder, reporter and materials handlers.)
2. Distribute the materials: one or more magnets (several different types and/or sizes) and paper clips
3. Ask students to find answers to one or more of these questions:
    - "How many paper clips can your magnet pick up?" Have students record their data. *(Hint: Record each team's highest number on a chart—or make a graph of the class results.)*
    - "How many paper clips can you hang in a string or row from your magnet?" Have students record their data. *(Hint: Record each team's highest number on a chart—or make a graph of the class results.)*
    - "Do different magnets pick up different amounts of paper clips?" Have students record their data and conclusions
4. Once students have had ample time to explore, ask them to share their discoveries. Add appropriate information to the class web.

Explanation

Following exploration, help students to verbalize what they learned and draw conclusions. Facilitate a class discussion so that the concepts explained in the next paragraphs will emerge or teach the concepts through enhancement, exploration or expansion activities.

Magnetic attraction functions in much the same way as the attraction found in static electricity. Furthermore, some of the most important real-world applications of electricity depend on the fact that an electrical current produces a magnetic field in its neighborhood. Principles of magnetism and magnetic attraction include the following:

- Magnetism is the ability to attract iron and certain other metals that have a molecular structure similar to iron. Magnets do not attract non-metallic objects. (Note: magnets do not attract aluminum.)
- One end of a magnet will always swing toward the north if freely suspended—the other will always swing south. The two ends are called the north and south poles of the magnet.
- Like magnetic poles repel—unlike poles attract.
- If a magnet is cut in two pieces, there will be a north and south pole of each magnet.
- The force of the attraction is directly proportional to the strength of the poles and inversely proportional to the square of the distance between them.
- Magnets can cause materials made from iron and similar metals to become magnetic. (This is why a long string of paper clips can be held by a magnet—even though some of the clips are not in direct contact with the magnet.)
- Stronger magnets have a stronger "pull" (e.g., they attract more paperclips).

Evaluation

Questions like those listed below can be used for testing, homework assignments, and similar evaluation techniques. When you observe students during learning activities, you can visually assess their learning. Assign and review journal entries to evaluate students' learning comprehension through their drawings and narratives.

Sample questions:

1. What kinds of objects to magnets attract? Explain.
2. What kinds of things do magnets not attract? Explain.
3. Why did the paper clips hang on the chain, even though they were not touching the magnet?

Observation: Use one or both or the exploration activities to observe whether students are grasping the concepts of magnetism. Record your assessments. Offer intervention for any students who are struggling to understand the concepts.

Journal assignment: List three new things that you learned about magnets from our magnet web. Explain why this new knowledge is interesting to you.

Extension activity

- For a homework assignment, have students find magnets in their home. They can either draw or list each magnet and record where they found it.

Resources for teachers

How Things Work by David McCauley. (Book and CD-ROM)

Mostly Magnets (AIMS Education Foundation, 1991.)

Electrical Connections (AIMS Education Foundation, 1991.)

101 Great Science Experiments by Neil Ardley.

Magnets and Electricity by Carson Dellosa.

Electricity and Magnetism (Creative Teaching Press #2807)

Electricity by Evan Moor. (ISBN 1-55799-293-2)

Magnetism and Electromagnets by Evan Moor. (ISBN 1-55799-292-43)

Bill Nye Web site (Internet address is listed in the Resources section, Appendix B.)

Bill Nye Video

See also, your local electric utility company. Many provide teaching materials and hands-on learning activities for students as a community service.

Resources for students

Science with Batteries (Usborne Science Activities)

Brush, Comb, Scrub: Inventions to Keep You Clean by Vicki Cobb.

What Magnets Do by Allan Fowler.

Where Does Electricity Come From? (Usborne Science Activities)

Science Book of Electricity by Neil Ardley.

Arthur's New Power by Hoban.

Blackout by Ann Rockwell.

What is Papa Up to Now? by Bourne.

Attractions Data Sheet

Team Members' Names ______________________

____

____

Item: List or draw each item your team will be testing.	**Prediction: Will this item be attracted by a magnet?**		**Is this item attracted by a magnet?**	
	Yes	**No**	**Yes**	**No**
1.				
2.				
3.				
4.				
5.				
6.				

171

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WALTER THE WALTZING WORM

Topic: Magnetic attraction

Learning objective

Students will discover that magnets can affect metal objects without touching them.

Process skills

- ○ Building models
- ● Categorizing or classifying
- ● Communicating
- ● Comparing
- ○ Controlling variables
- ● Experimenting
- ● Hypothesizing
- ● Inferring
- ● Interpreting data
- ○ Measuring
- ● Observing
- ○ Ordering
- ● Predicting
- ● Recognizing relationships
- ● Recording

Ohio 4th-grade science proficiency outcomes

- ● 1
- ● 2
- ○ 3
- ○ 4
- ● 5
- ● 6
- ○ 7
- ● 8
- ● 9
- ○ 10
- ● 11
- ● 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup	10 minutes
Exploration	15 minutes
Cleanup	5 minutes

Key science principle

- Magnetic poles (i.e., same poles of magnets repel, opposite poles attract)

Materials

Pennies

Pencils

Long nails (3 inches or longer)*

Tape*

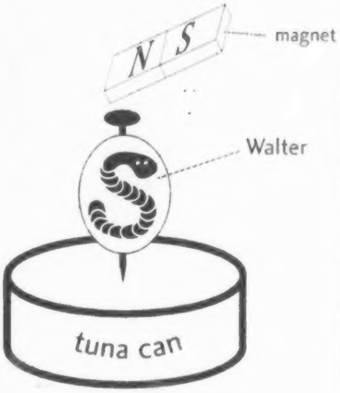
Bar magnets

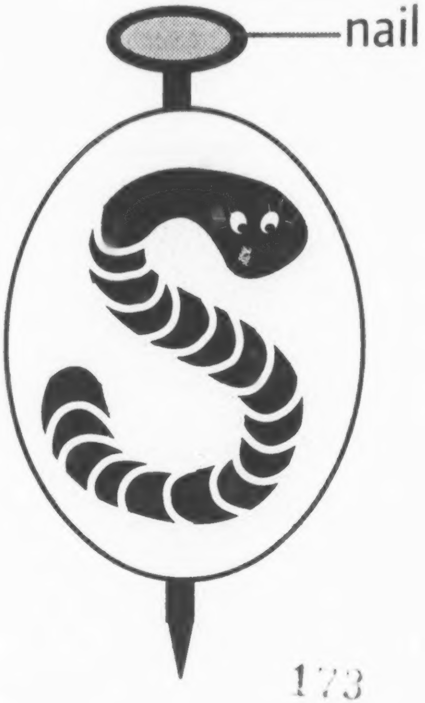
Pictures of Walter the Waltzing Worm* (Create several copies in advance.)

Tuna cans or other objects such as pots, steel buckets, or stainless steel bowls) (optional)*

Flip chart paper

* These materials should be used to assemble materials that students will use to make Walter dance.





Safety tips

- Caution students against putting magnets in their mouths.
- Instruct students on the appropriate and safe use of all materials required for this activity.
- Monitor younger students during these learning activities.

Engagement activities

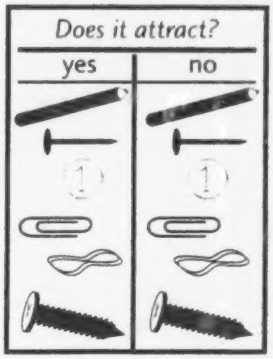
1. Create a learning center for exploring magnets. Include a collection of objects that will and will not attract to magnets, e.g., crayon, nail, paper clip, eraser, screw, ball, pencil, coin, rubber band. Also include a few of each of the items listed in the materials section above.
2. Organize students for exploring and experimenting in the center. Distribute data sheets and instruct students to record their results on a graph.

Note: The first "Attractions" learning activity could be used as an engagement activity for "Walter the Waltzing Worm."

Exploration activities

Hint: For maximum learning from this exercise, conduct it as a center activity so that students can explore and discover on their own.

1. Introduce Walter the Waltzing Worm to the class.
2. Explain that Walter loves to waltz and you want to tape him to an object so he can **dance with your magnet**. Ask students to help you pick objects from the learning center that will make Walter dance.
3. List their ideas on large chart paper.



4. Demonstrate the testing process students will use by displaying 3 objects (Note: Do NOT use a penny, pencil, or nail—students will be doing their own testing with these). Ask students to predict which object(s) will help Walter dance.
5. Record their predictions on a chart similar to the sample chart shown here.

6. Test the objects by having Walter "dance" with your bar magnet on the top of an up-side down tuna can or another item (e.g., a pot, steel bucket, stainless steel bowl).
7. Circle the results on the chart. If the result was the same as the prediction, make note of it. If the result different than the prediction, discuss it.
8. Distribute pictures of Walter and give students time to color and cut out their pictures.
9. Instruct students to pick an object (i.e., a penny, pencil and nail), predict whether or not it will make Walter dance, then experiment with the object by taping Walter to it and testing it with a magnet. Hint: Provide extra copies of Walter so students can conduct multiple tests.
10. As a class, discuss the following questions:
    - "Which predictions needed to be changed?" Ask a few students to share their changes.
    - "Does the magnet have to touch the metal in order to make Walter waltz?"
    - "How far away can we hold the magnet and still make Walter waltz?"
    - "Are both ends of the magnet the same?" Help students recognize how they are different.

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge or teach the concepts through enhancement, exploration or expansion activities.

Magnetic attraction functions in much the same way as the attraction found in static electricity. Furthermore, some of the most important real-world applications of electricity depend on the fact that an electrical current produces a magnetic field in its neighborhood. Principles of magnetism and magnetic attraction include the following:

- **Magnetism** is the ability to attract iron and certain other metals that have a molecular structure similar to iron. Magnets do not attract non-metallic objects. (Note: magnets do not attract aluminum.)
- One end of a magnet will always swing toward the north if freely suspended—the other will always swing south. The two ends are called the **north and south poles** of the magnet.
- Like magnetic poles **repel**—unlike poles **attract**.
- If a magnet is cut in two pieces, there will be a north and south pole of each magnet.
- The force of the attraction is directly proportional to the strength of the poles and inversely proportional to the square of the distance between them.
- Stronger magnets have a stronger "pull."

Evaluation

Questions like those listed below can be used for testing, homework assignments, and similar evaluation techniques. When you observe students while they experiment, you can visually assess their learning. Assign and review journal entries to evaluate students' learning comprehension through their drawings and narratives.

Sample questions/written assessments:

1. Which objects helped Walter dance? Why?
2. Which objects did **not** help Walter dance? Why?
3. Use the "Attractions" data sheet as a pretest. As a post-test, ask students to review their data sheets, adding new ideas and deleting inaccurate ones.

Observation: Have students share their knowledge of magnetic attraction. They can share as "buddies" or they can teach a lesson about magnets to a small group of students from another class. Observe and record whether or not they can demonstrate what they have learned.

Journal assignment: What force causes objects to be attracted to magnets?

Extension activities

- Allow students to experiment with repelling objects by using the opposite end of the bar magnet. Ring magnets can also be used to repel and attract objects—and other magnets.
- Have students make their own magnets. Instruct them to rub their scissors with a clean cloth and try to pick up paper clips. Ask them questions like:
  - "How many clips can you pick up?"
  - "Does rubbing the scissors more allow you to pick up more clips?"
  - "Should you rub one way or back and forth?"
  - "How long do the scissors stay magnetized?"

Subject integration

History. Have students read about the history of magnets. They can also study rocks (e.g., lodestone) and research the discovery of magnets. Give them an opportunity to summarize what they learned in a story, a written report, or a poster board display.

Language Arts. Instruct students to write poems or stories about Walter. Let them present their stories and poems in a drama featuring Walter and a magnet.

Music. Sing "Walter the Waltzing Worm," Hap Palmer, Activity Records, NY (cassette tape).

Music and/or **Physical Education**. Arrange for waltzing lessons with your class (e.g., teach students yourself or have a colleague or guest instructor teach them). Then, let Walter waltz with them.

Resources for teachers

Mostly Magnets (AIMS Education Foundation, 1991.)

Electrical Connections (AIMS Education Foundation, 1991.)

Magnets and Electricity by Carson Dellosa.

Electricity and Magnetism (Creative Teaching Press #2807)

Magnetism and Electromagnets by Evan Moor. (ISBN 1-55799-292-43)

See also, your local electric utility company. Many provide teaching materials and hands-on learning activities for students as a community service.

Resources for students

First Step Science: My Magnet by R. Pressling. (Garreth Stevens Publishing, 1994.)

Science Secrets: Magnets by J. Cooper. (The Rourke Corp., Inc., 1992.)

Experiments With Magnets and Electricity by M. Walley. (Lerner Publications Co., 1994.)

What Magnets Do by Allan Fowler.

What is Papa Up to Now? by Bourne.

Notes

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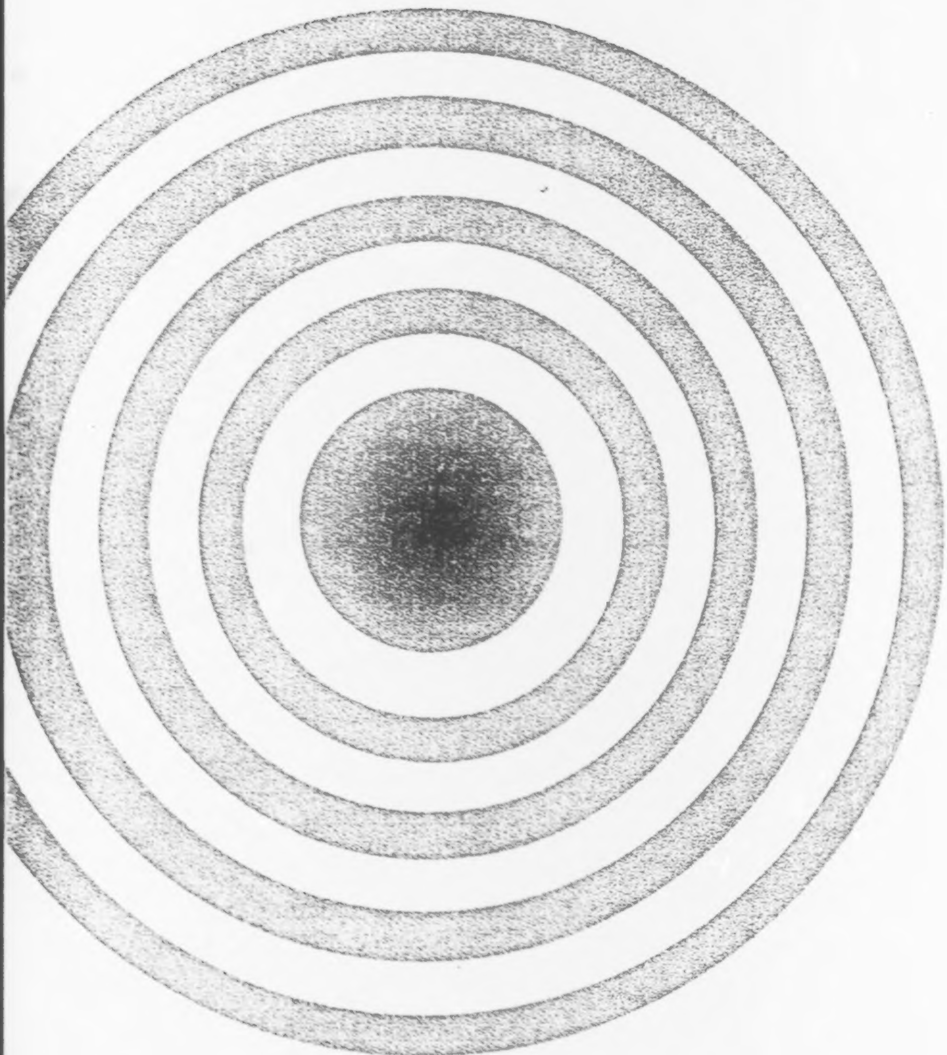


FUN WITH PHYSICS:

Real-Life Problem Solving for Grades K-3

Exploring Heat

Learning Activities **Page**

Sun Power .173

Some Like it Hot .181

A Disappearing Act .189

Dancing Quarters .197

Hot Foot—Cold Foot .203

A Bunch of Hot Air .211

Putting It On: What's the Weather Like? .217

Keep It Cool .223

EXPLORING HEAT VOCABULARY

Absorption

Cold

Condensation

Conduction

Evaporation

Friction

Heat

Molecules

Temperature

Thermometer

Weather

SUN POWER

Topic: Using a thermometer to measure the sun's heat

Learning objectives

Students will:

1. Recognize the sun as a heat source.
2. Make inferences and predictions about which outdoor places will produce the most heat.
3. Measure and record the results of the learning activity.

Process skills

Building models
Categorizing or classifying
● Communicating
● Comparing
Controlling variables
Experimenting
● Hypothesizing
● Inferring
● Interpreting data
● Measuring
● Observing
Ordering
● Predicting
● Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

1
● 2
● 3
4
● 5
6
● 7
● 8
● 9
10
● 11
12

Refer to Appendix F, p. 353, for a description of outcomes.

Time estimates

Setup	10 minutes
Exploration	90 minutes
Cleanup	5 minutes

Key science principles

- Law of thermodynamics, i.e., heat always flows spontaneously from hot to cold
- Thermal energy sources

Materials

Color-coded thermometers (see example)
Newsprint to record students' predictions
Tape to label thermometers
Rubber bands
One thermometer diagram for each actual thermometer (See the worksheet on p. 178.)

Safety tips

- Do this activity when the class will be outdoors alone and have private access to thermometers.
- Use plastic thermometers.

Engagement activities

1. Discuss with students that the higher the line on a thermometer, the hotter the temperature. Discuss the meaning of the colors and how they coincide with the temperature, i.e., 0-20° (white), 21-40° (blue), 41-60° (yellow), 61-80° (orange), above 80° (red).
2. Throughout the year, use a thermometer as a daily activity when discussing the weather. Graph the temperature each day. See the worksheet on p. 179.

Exploration activity

1. Ask students to predict places outside that they think are the hottest (e.g., blacktop, concrete, grass, sliding board, shade and swings). List students' responses on the newsprint.
2. Take students outside and let them put thermometers on the places they selected. Label each thermometer with the site for later use.

3. Wait 30 to 60 minutes.
4. Help students collect the thermometers, placing a rubber band around each to mark the registered temperature.
5. Instruct students to record the colors and actual temperatures on the thermometer diagrams.
6. Compare the thermometer diagrams and facilitate a discussion concerning:
   - Which site was the hottest?
   - Which place was the coolest?
   - Did some places have the same temperature? Help students discuss their thoughts about why this happened.

Explanation

Following exploration, help students to verbalize what they learned. Facilitate discussion so that the concepts explained in the next paragraph will emerge.

This learning activity allows students to recognize the impact of the sun's heat upon different surfaces. Studying the sun as a heat source gives students a basic understanding of the law of thermodynamics that states, "Heat always flows from something hot to something cooler." Exploring site temperatures with a thermometer helps students learn that heat is absorbed and reflected differently on unlike surfaces. They also learn that warmth on the surface and in the air spreads to warm the fluid inside the thermometer, causing it to expand and rise. Students' understanding of the impact of the sun's heat upon the thermometer can be used to help them understand its impact upon the unlike surfaces.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. When you observe, you can visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. Would blacktop or cement be hotter on bare feet?
2. Where would you go outside to get cooler?

Observation: Was the child able to accurately record the temperature on the thermometer?

Journal assignment: What happened to the temperature gauges on the thermometers? Explain how this happened.

Extension activities

- Order thermometer diagrams from hottest to coolest, then graph these results.
- Repeat the entire learning activity on a hotter or cooler day, then compare the results with the graph created for the first experiment.
- Read *Temperature and You* by Betsy and Giulio Maestro (Lodestar Books, 1990).
- Explain to students that other things produce heat. Let them explore this concept with activities like rubbing their hands together (explain that when two things rub together, heat is produced), blowing on a thermometer, and placing fingers first on a light bulb then on a thermometer.

- Explore the point on a thermometer where water turns to ice and where water turns to steam. A good demonstration activity follows: Place a thermometer into a jar of ice. Notice how close it will read to 32 degrees Fahrenheit (F) or 0 degrees Centigrade (C). After the thermometer rises to room temperature, place it just above the surface of boiling water. It should read near 212 degrees F or 100 degrees C.
- Explore the idea of solar heat. Explain that some houses have special solar panels on the roof that use the sun's heat to keep the house warm and provide warm water for the house. Discuss how people who use solar heat do not need to pay for electricity or fuel, but building and maintaining a solar home is quite expensive.

Subject integration

Health. Students can explore body temperature. Normal body temperature is between 98 and 99 degrees F. Explore why body temperature rises and falls when we're sick.

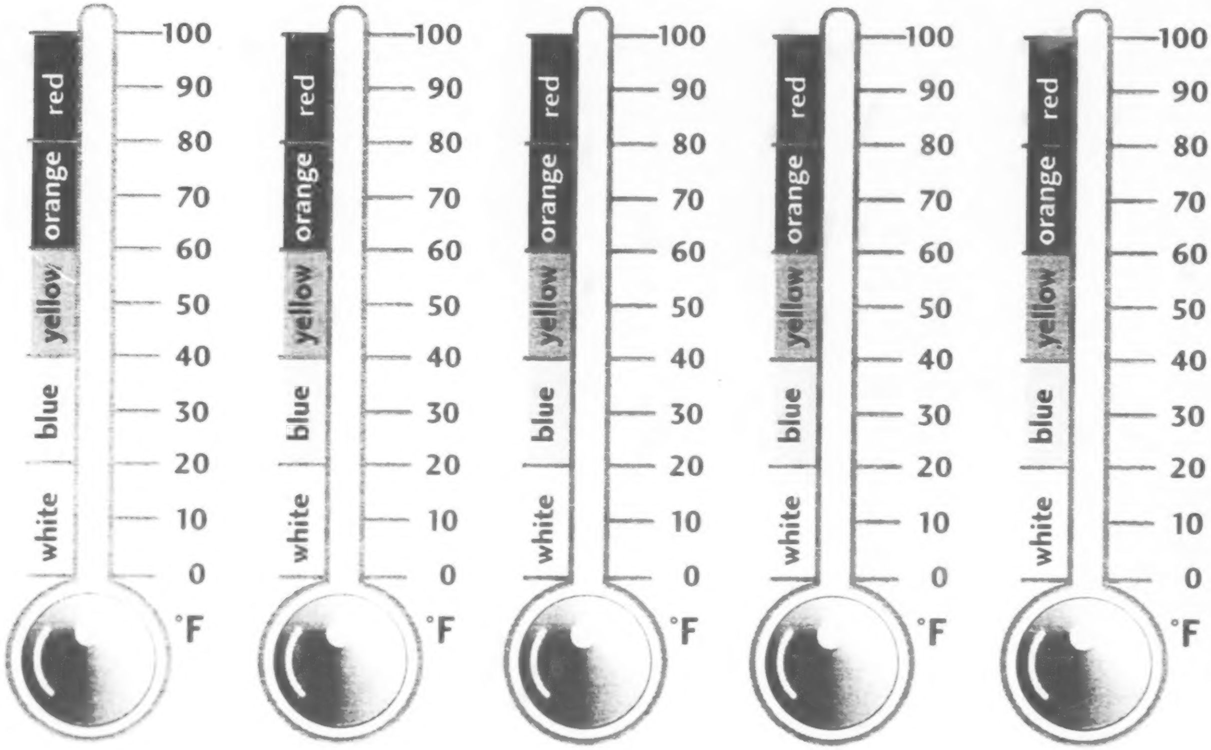
Language Arts. Read *Hot and Cold* by Allan Fowler (Children's Press, 1994.) Ask students to think of "hot" and "cold" words. Record these on a chart for use in writing assignments.

Geography. Read *Welcome Back Sun* by Michael Emberley (Little, Brown and Company, 1993), a story about the mountain villages of Norway in which the sun almost completely disappears between the months of September and March. Find Norway on the globe. Facilitate a discussion, drama or similar learning activity to help students "experience" the Norway situation.

Resources for teachers

Mudpies to Magnets — A Preschool Science Curriculum by Robert A. Williams, Robert E. Rockwell, and Elizabeth A. Sherwood. (Gryphon House, Inc., 1987.)

SUN POWER AND SOME LIKE IT HOT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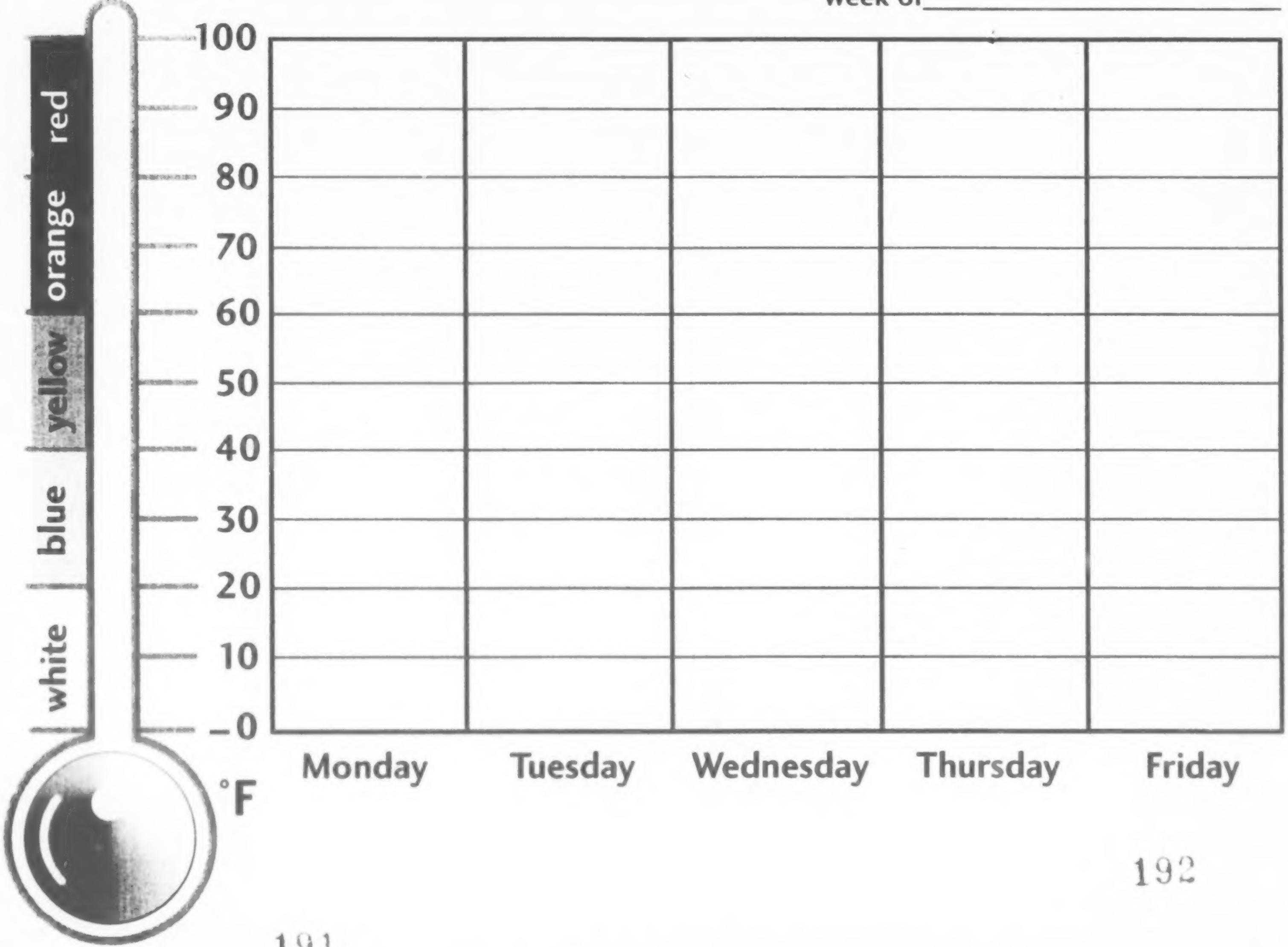
SUN POWER

Week of______________________



Notes

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SOME LIKE IT HOT

Topic: Resistance and absorption of heat in different objects and colors

Learning objectives

Students will:

1. Observe the effect of the sun's heat on different objects and colors.
2. Observe that objects have different resistances to the sun's heat.

Process skills

Building models
Categorizing or classifying
● Communicating
● Comparing
Controlling variables
● Experimenting
Hypothesizing
● Inferring
● Interpreting data
● Measuring
● Observing
Ordering
● Predicting
● Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
● 3
4
● 5
● 6
● 7
● 8
● 9
10
● 11
12

Refer to Appendix F, p. 353, for a description of outcomes.

Time estimates

Setup..................10 minutes
Exploration..........90 minutes
Cleanup....... ....10 minutes

Key science principles

- Thermal resistance (opposition to the flow of heat energy)
- Law of thermodynamics, i.e., heat energy always flows spontaneously from hot to cold

Materials (one set for each group of students)

5 identical clear jars (large enough for thermometer to fit inside with lid on.)

5 color-coded thermometers

Black paper

White paper

Soil

Water

Sand

5 Diagrams of Thermometers (see p. 178)

Newsprint for tally

Data sheets (if appropriate for grade level, see p. 187)

Hint: You can use identical tin cans covered with colored construction paper instead of glass jars.

Safety tips

✚ Use plastic jars and plastic thermometers, if available.

Engagement activity

Complete the Sun Power learning activity, which starts on p. 173.

Exploration activity

1. Form teams of 3-5 students each. Have them choose roles of recorder, reporter, temperature readers and materials manager(s).
2. Drawing on students' experience from the Sun Power learning activity, ask them to make the following predictions:
    - What color will absorb the most heat and become the hottest?
    - Which color will resist the heat and stay the coolest?
    - Will the water absorb or resist the sun's heat? Soil? Sand?
3. Record and tally the predictions on newsprint.
4. Place black paper in one jar, and white paper in another jar. Fill the third jar with dry soil, the fourth jar with water, and the fifth jar with sand. Position the thermometers in the jars so they can be read without removing the lids.
5. Place all jars in a sunny location and leave them for about an hour.
6. Read the thermometers in an hour.
7. Record the colors and actual temperatures on the thermometer diagrams.
8. Compare thermometer diagrams and discuss which materials were the hottest.
9. Discuss the color of the objects and the actual temperature on the thermometer, explaining how different colors are affected by heat.
10. Compare results against predictions.

Explanation

Following exploration, help students verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge.

Thermal resistance means opposition to the flow of heat energy. The dark soil, rough sand, and black paper absorb the sun's heat more quickly than the "shiny" water and white paper because the latter are more resistant to the sun's heat. The faster heat energy moves from one molecule to another inside a material, the less resistance.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. Observation allows you to visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. Would the inside of a car stay cooler if it had a white or black interior?
2. Would you rather walk barefoot in the sand or soil on a hot day? Why?

Observation: Ask students to draw a picture of what they would wear on a very hot day. Instruct them to think about color in their drawings.

Journal assignment: Think about how the colors in our experiment absorbed or reflected the heat. Based on what you learned, which color might you wear outside in the winter? Why? Would you wear the same color in July? Why or why not?

Extension activities

- Students choose objects made of different materials (e.g., metal, wood, glass, plastic, foam) and perform the Some Like it Hot learning activity with these, measuring the temperature of these objects.
- Make "sun treats" to observe the effect of the sun's heat on different foods. For example, line ½ of a muffin tin with foil baking cups and the other ½ with paper baking cups. Place 1 marshmallow and 1 chocolate square in each cup. Place the muffin tin in direct sunlight and observe how the ingredients respond. Observe which treats are ready to eat first, those in the paper or foil cups. Enjoy!
- Set a glass aquarium covered with a glass lid in the sun. After an hour, feel the inside of the aquarium. Help students explain how some of the energy from the sun gets trapped inside the aquarium. Apply this knowledge to students' daily lives by facilitating a class discussion about why pets should not be left in closed vehicles.

Subject integration

Geography: Find desert regions with the students on the globe. Discuss the type and color of clothing people in these regions wear. Describe the color of the land and surroundings. *Hint: Use drawing and/or picture books, videos or other visual aides to illustrate clothing and terrain.*

Art: Make "sun pictures" with black construction paper. Ask students to cut out designs in black construction paper, then tape the black designs to a piece of dark-colored construction paper. *(Alternative: Place an object such as a key or pencil on the construction paper.)* Put the sun pictures on a sunny window sill for several days or weeks. (The longer the paper is left in the sun, the stronger the shadow appears on the colored construction paper.) Remove the black design or object from the colored paper and observe the design which is faded there. Hint: Treated paper for making sun prints is available from art and science stores.

Resources for teachers

More Mudpies to Magnets — Science for Young Children by Elizabeth Sherwood, Robert A. Williams, and Robert E. Rockwell. (Gryphon House, Inc., 1990.)

The Science Book Of Hot & Cold by Neil Ardley. (Gulliver Books, 1992.)

Some Like It Hot Data Sheet

Reporter's Name ______________________________

Recorder's Name ______________________________

Temperature Reader's Name(s) ______________________________

QUESTION: Which color will absorb the most heat & become hottest?

PREDICTION: Make a prediction and why you think this will happen.

We predict ______________________________

EXPERIMENT: Draw a picture of what you did.

RESULTS:

Temperature in the ____________________ jar was ____________________.

Temperature in the ____________________ jar was ____________________.

Temperature in the ____________________ jar was ____________________.

Temperature in the ____________________ jar was ____________________.

Temperature in the ____________________ jar was ____________________.

CONCLUSION:

We found that the jar with ____________________ was hottest, so it absorbed the most heat.

Notes

201

A DISAPPEARING ACT

Topic: Evaporation and the heat cycle

Learning objectives

Students will:

1. Control variables to discover that heat speeds up the flow of evaporation.
2. Observe the opposite effect of evaporation—condensation.
3. Integrate knowledge from objectives 1 and 2 to develop an understanding of the water cycle.

Process skills

○ Building models
○ Categorizing or classifying
● Communicating
● Comparing
Controlling variables
● Experimenting
● Hypothesizing
● Inferring
● Interpreting data
● Measuring
● Observing
○ Ordering
● Predicting
● Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

1
● 2
● 3
○ 4
● 5
● 6
● 7
● 8
● 9
○ 10
● 11
○ 12

Refer to Appendix F, p. 353, for a description of outcomes.

Time estimates

Setup . . . . 10 minutes
Exploration . . . . 1 day
(monitor throughout the day)
Cleanup . . . . 5 minutes

Key science principles

- Law of conservation of energy, i.e., energy cannot be created or destroyed
- The flow of heat and liquids
- Evaporation and condensation

Materials

Paint brush for each student
Large glass jar
Tin pie pan
Water
Chalk or yarn
Ice cubes
Very hot water

Safety tip

✚ Only the teacher should handle the very hot water and glass jars.

Engagement activities

1. Help students recognize the evaporation experiences they have in daily living by discussing some common ones, like what happens to their wet hair after they wash it? And how do paintings dry?
2. On a sunny day, allow students to go outside and paint with water. Observe and discuss what happens to the water as it evaporates. Next help them find a shady spot in which to paint. After observing the water evaporate again, encourage students to discuss which of the two painting spots made the water evaporate more quickly. Help them to predict why.
3. Review the terms "circumference," "depth," and "diameter."

Exploration activity

1. After a heavy rain, take students outside to a paved area such as a sidewalk or playground.
2. Remind them about the painting experiment (engagement activity #2 above).

3. As a class, choose two puddles, one in the shade and one in the sun. *(Hint: During dry seasons, create your own puddles outside by filling 2 liter bottles with water and emptying them in both sunny and shady spots.)*
3. Have 2 students draw chalk circles around the puddles' edges. *Hint: You can also measure the perimeter with yarn and compare lengths.*
4. Draw another line about every hour to measure how quickly the puddles are evaporating. (Note: puddles sometimes evaporate on the inside first, so the perimeter won't always shrink.)
5. Observe which puddle is evaporating the quickest.
6. Compare the size of the puddles and discuss how heat makes evaporation occur faster.
7. Perform the following demonstration after students have developed a firm understanding that heat speeds up evaporation:
    a. Fill a glass jar ⅔ full with very hot water. (This helps students to observe the steam rising and remind them about the process of evaporation.)
    b. Fill a pie tin with ice. Have students observe that condensation forms on the outside of the pie tin.
    c. Place the pie tin on top of the glass jar, positioning it so that one side of the tin sits across the jar opening. Instruct students to watch the condensation drops. (They will become heavy enough to fall back into the jar.)
    d. Explain that when cold and hot air meet, rain occurs. Facilitate a class discussion to help students apply this knowledge to a rainy day. For example, as students answer your questions about rain forming in the "sky," draw a picture on the board of hot and cold air meeting in the sky and rain coming from it.

Explanation

Following exploration, help students verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge.

Changing liquid water into vaporized water requires energy, usually in the form of heat. The law of conservation of energy states that energy can be changed from one form to another, but energy can never be created or destroyed. This law can be observed through **evaporation** (changing of water into water vapor) and **condensation** (cohesion of water molecules into a liquid.) The earth consistently retains about the same amount of water, but it's always on the move in a never-ending cycle. Water vapor in the atmosphere condenses to form clouds and fog. Water falls to the surface as rain, hail, and snow. Then it travels around on the surface and filters through the soil. Meanwhile, water is passing from the surface back into the air, as it evaporates to form water vapor. The entire cycle is driven by heat energy from the sun.

Evaluation

Questions like those listed below can be used for testing, homework assignments, and similar evaluation techniques. When you observe, you can visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. Where does water go when it evaporates?
2. What causes raindrops to form?

Observation:

1. Have students illustrate the water cycle (e.g., picture, drawing, flow chart).
2. Put water on a chalkboard. Ask students, "How can we speed up evaporation?" List their suggestions, then try them. Have students explain the results, verbally or in their journals.

Journal assignment: Where did the liquid from the puddles go and how?

Extension activities

More puddle activities:

- Record the puddles' evaporation in the classroom using construction paper for puddles. Use one color of construction paper for the sun puddle, and another color for the shade puddle. Measure each puddle's diameter every hour. Cut the paper to match the evaporation of the puddle. Compare the size of the parts cut from the sun puddle with those from the shade puddle.
- Try the experiment in different kinds of weather. Will the puddles dry faster on a sunny or cloudy day? Do the puddles disappear faster on a calm or windy day? *Hint: The sun and wind will dry the puddles faster.*
- Record the physical characteristics of the puddles on a data sheet, e.g., circumference (how big around), depth (how deep), and diameter (how far across). See the data sheet, p. 196. *Hint: This exercise allows students to practice taking measurements, too.*

More evaporation activities:

- Have students soak two identical paper towels in water and hang them on a clothesline that has been strung across the room. Fold one towel over the line at the towel's center. Attach the second towel with clothes pins so it lays in a single layer. Let students predict and observe which towel dries faster. Try this activity out of doors on a windy day and compare the drying rate with the indoor clothesline results. Then help students relate their learning from the paper towel experiment to how desert cacti hold water.
- Experiment with different liquids to see if they evaporate at different speeds (e.g., Koolaid, tea, water, salt water, lemon juice).
- Fill a vaporizer with water. Place a strip of masking tape from top to bottom of the vaporizer. Mark the water level on the tape. Have students predict where the water level will fall at day's end. Mark their predictions on the vaporizer. Turn on the vaporizer and let it run until the end of the day. Mark the actual end-of-the-day water level. Then, check students' predictions to see who came the closest. Hint: Check to see if students have allergies before doing this activity.
- Experiment with drying foods such as grapes, apples, and bananas. Graph the results. Help students conclude which food dries the quickest.
- Read *Sun up, Sun down* by Gail Gibbons (Harcourt, Brace & Company, 1983) to discover some facts about the sun.
- Read *Skyfire* by Frank Asch (Scholastic, 1984) and explore how rainbows form. *Hint: Drops of water are like a prism. White light bends through the prism of the rain. Some rays bend more than others, separating the light into different colors.*

Subject integration

Language Arts. Read *Sun Up* by Alvin Tresselt (Lothrop, Lee, & Shephard Books, 1991), which is a story about a farm family working on a hot summer day until a sudden thunderstorm drives them all home. Have students list rain words. Record them on a chart and create a class poem.

Social Studies and Folklore. Read *Rainbow Crow* retold by Nancy Van Laan. (Dragonfly Books, 1989.) This Native American legend describes the earth's first snowfall, which grows so deep that the animals disappear beneath it. The rainbow crow volunteers to fly toward the sun to ask the Great Sky Spirit for help. Such a review of snowfall can begin a study of Native Americans and folklore, too.

Math. A Disappearing Act and its extension activities incorporates many forms of measurement, as well as measuring concepts like perimeter. Therefore, these activities would be quite useful for learning practical math.

Puddles Data Sheet

Name(s) ______________________

Date ______________________

Time ______________________

	Shade Puddle	Sun Puddle
Circumference		
Depth		
Diameter		

209

DANCING QUARTERS

Topic: The rising and expansion of warm air

Learning objectives

Students will:

1. Observe that pressure results from heated air.
2. Predict the outcome of an experiment, based on knowledge gained from previous heat activities.

Process skills

○ Building models
○ Categorizing or classifying
● Communicating
○ Comparing
○ Controlling variables
● Experimenting
● Hypothesizing
● Inferring
○ Interpreting data
○ Measuring
● Observing
○ Ordering
● Predicting
● Recognizing relationships
○ Recording

Ohio 4th-grade science proficiency outcomes

○ 1
○ 2
○ 3
○ 4
● 5
● 6
○ 7
● 8
● 9
○ 10
● 11
● 12

Refer to Appendix F, p. 353, for a description of outcomes.

Time estimates

Setup ....15 minutes
Exploration ....75 minutes
Cleanup ....10 minutes

Key science principles

- Thermal pressure
- Law of thermodynamics, i.e., heat energy always flows spontaneously from hot to cold

Materials

Thermometer
Large bowl
Empty plastic pop bottle
Balloons
Rubber band
Small empty glass pop bottle that has been chilled in the refrigerator (1 for every 2 students)
Quarter (1 for every 2 students)
Ice water
Hot water
Chart paper
Marker

Safety tips

- **Only the teacher** should pick up glass bottles.
- For K-1 students, the teacher should distribute quarters **only** when it's time to use them and remind students that coins do not belong in mouths.
- When using boiling water, remind students to keep their hands in their laps.

Engagement activities

1. Allow students to experiment with a thermometer by asking them what they think will happen if they cup their hands around it. After exploring this, discuss the results of heat from the students' hands causing the thermometer to rise.
2. Inflate 2 balloons and ask students to predict what will happen if they put one in a cold place (such as a refrigerator) and one in a warm place (like in direct sunlight). Talk about students' predictions. Place the balloons in the cold and warm locations. Observe and discuss the results.

3. Conduct the following demonstration for the whole class:
    a. Fill the large bowl with ice water and stand the empty bottle in it.
    b. After 5 minutes, place the balloon over the top of the bottle and secure the balloon with a rubber band.
    c. Remove the bottle from the ice water and empty the water from the large bowl.
    d. Fill the large bowl with boiling water.
    e. Place the bottle in the hot water and observe. *Hint: The balloon will inflate.*

Exploration activity

1. Provide pairs of students with a chilled glass pop bottle and a quarter.
2. Moisten the top of each pop bottle by having each student dip a finger in water and rub the top of the bottle.
3. Have students place a quarter on the top of each bottle.
4. Ask students to recall what they have learned about hot air rising and expanding. Then ask them to suggest ways to make the quarter come off of the top of the bottle without touching the quarter or moving the bottle. Record student responses. (Have older students record their own predictions.)
5. Talk through possibilities and allow students to try their ideas. If they have difficulty generating ideas, use questions such as "How can you make the bottle warm?" *Hint: Encourage students to cup their hands around the bottle. Heat from their hand will move the quarter up and down.*

6. Evaluate students' predictions from step 3. Cross out inaccurate ones, and add any new methods that worked in the experiment but were not originally listed. *Hint: Use this review process to demonstrate that the scientific discovery includes much trial and error. Encourage students' creativity, thinking, and risktaking by explaining that scientists often find a solution by eliminating all other possibilities first.*

Explanation

Following exploration, help students verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge.

When an object is heated, the warmer object spontaneously passes on some of it's heat energy to cooler objects beside it. This is called **conduction**. The increased heat of the bottle conducted heat to the air inside it and caused an increase in the pressure and volume of the air inside the bottles and the hot air balloon (expansion). The expanded air caused the balloon to inflate and the quarters to move up and down.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. When you observe, you can visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. How did you make the quarter move?
2. What energy source caused it to move?
3. What created the energy source?

Observation: Were students able to think of using the warmth from their hands independently?

Journal assignment: Explain how you moved the quarter from the top of the bottle.

Extension activities

- Observe a hot air balloon. Explain that heat powers a hot air balloon. The flame at the balloon's opening heats the air inside the balloon, causing the air to expand. The air becomes lighter in expansion, which allows the balloon to rise.
- Study the two French brothers, who had the first unmanned hot air balloon flight in 1783. Their balloon climbed to 35 feet.
- Cook some popcorn. Discuss why it pops. *Hint: Each kernel of corn contains moisture inside its hard, airtight shell. Heat causes the moisture to expand—creating pressure. The pressure explodes the corn.*
- Read *Thundercake* to study what causes thunder. *Hint: Thunder results when suddenly heated air collides with rushing cold air. When lightning streaks through a cloud, it moves so fast that it heats air around it very quickly. Cold air pushes under the lightning—heating air so fast that it creates a loud crack—thunder.*

Subject integration

Language Arts. Read *Thundercake* by Patricia Polacco (Scholastic Inc., 1990) and review the cause of thunder.

Physical Education and/or Music. Create the sounds of a thunderstorm with students.

1. Have students imitate what you do:
    a. Rub your hands together
    b. Snap your fingers
    c. Clap your hands
    d. Pat your legs
    e. Stomp your feet
2. Then work backward until the "storm" has stopped.
3. Facilitate a discussion about what this "storm" was like.

Math. Read *The Popcorn Book* by Tomie dePoola and conduct measurement activities with popcorn.

Resources for teachers

Physics for Kids — 49 Easy Experiments with Heat by Robert W. Wood. (TAB Books, 1990.)

HOT FOOT/COLD FOOT

Topic: Conductors of heat energy

Learning objectives

Students will:

1. Comprehend the characteristics of a good conductor of heat energy.
2. Gather knowledge about the molecular actions that produce heat energy.

Process skills

○ Building models
● Categorizing or classifying
● Communicating
● Comparing
○ Controlling variables
○ Experimenting
○ Hypothesizing
○ Inferring
○ Interpreting data
○ Measuring
● Observing
○ Ordering
○ Predicting
○ Recognizing relationships
○ Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
● 3
○ 4
○ 5
● 6
● 7
○ 8
○ 9
○ 10
● 11
● 12

Refer to Appendix F, p. 353, for a description of outcomes.

Time estimates

Setup . . . . 5 minutes
Exploration . . . 20 minutes
Cleanup . . . . 5 minutes

Key science principle

- Heat energy and conduction

Materials

Paper

Pencil

1 1/2-foot strip of aluminum foil

Carpet sample square (or small throw rug)

Red, pink and blue markers

Flip chart paper

How Does It Feel? data sheets (See p. 210)

Safety tips

- Remind students to **walk** with pencils, especially outside.
- Remind students to watch for sharp objects when exploring with hands and bare feet.
- Conduct this exploration activity on a sunny, warm day.

Engagement activity

Prepare students to focus on discerning hot and cold through touch with a relevant book, video or game. For example, facilitate a simple game of "What's Hot, What's Cold" by assigning a hot side and a cold side in the room. Then let students choose an object from pictures in a shoe box. Each student picks, stands, and names the object for the class. Then the class sends the student to the appropriate side of the room. *Hint: Encourage students who have already been sent to their respective areas to act hot or cold.*

Exploration activity

1. Divide students into groups of 3-4 and send them outside with a data sheet and pencil (or paper and markers for younger students) for each group.
2. Have students remove their shoes, and encourage them to explore different surfaces (e.g., grass in the sun, grass in the shade, blacktop, gravel, tree trunks, metal basketball/tetherball poles) with their hands and feet.
3. Instruct students to record the temperature they "felt" in each area (i.e., hot, warm, or cool). Younger students can draw pictures of the surfaces and color each—red for hot, pink for warm, and blue for cool—to record the temperature.
4. Return to the classroom.
5. Distribute a piece of foil and a carpet square to each group.
6. Show students how to position the foil and carpet square on the tile floor beside each other.
7. Allow both to remain undisturbed for at least 10 minutes so they can reach room temperature.
8. During the waiting period, facilitate a class discussion about students' outdoor exploration. Sample questions include:
    - "Did you observe any differences in the objects you explored?"
    - "If yes, what?"
    - "Which ones felt hot, warm, cold?" (Record responses on a flip chart.)
    - "What do you think caused the warm objects to get warm?"
    - "Why didn't the cool objects get warm, too?"
    - "What might we conclude about each of the objects?"

Hint: Students may struggle with answering the last question. Some may say something like, "Warm objects hold heat and cold objects don't." Encourage their efforts with, "You're getting warmer!" Then explain that all objects contain little "things" that we can't see, called **molecules**. *(Draw an example on the board.) In a good conductor of heat, one molecule receives* **heat energy** *and starts bouncing around. During these jerky motions one molecule bumps into a molecule nearby, causing it to bounce around and that one bumps into another and so on until every molecule is moving. The faster the molecules move, the better the object can* **conduct** *heat. Some materials are not very good heat conductors; its molecules do not move very easily, and they feel cool to the touch.* Encourage students to experiment with these concepts with the foil and carpet squares.

Alternative: You could explain molecular concepts during engagement activities and simply review them here.

9. Instruct each group member to put one bare foot on the aluminum foil and the other on the carpet simultaneously and to notice the "felt" temperature of the aluminum piece and that of the carpet.

10. Bring the class back into one group and ask them:
    - "Was there any difference between the felt temperature of the foil and the carpet?"
    - "If yes, what?"
    - "What might this say about each?" (Remind students about their molecule learning.)
    - "Many other materials could feel cool and hot. How could we test them?"
11. Record students' answers on a flip chart or chalkboard.

Hint: If time is limited, use the foil and carpet experiment as an extension activity.

Explanation

Following exploration, help students verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge.

Molecules in metals and aluminum can move around easily and are good conductors of heat energy. (Good heat conductors are also good electrical conductors.) The carpet is a poor heat conductor because its molecules move slower and actually block heat loss from your foot. **Aluminum feels colder than the carpet because it is a good heat conductor and the heat from your foot starts moving through the metal.** Things feel cold to your touch when heat energy is drawn away from your skin; things feel warm when heat energy is transferred to your skin.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. When you observe, you can visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:
Create a quiz or test from the same questions used for group discussions in the engagement and exploration activities.

Use the same questions for one-on-one interviews with students, checking to see if their answers show an understanding of heat conductors and the action of heat energy.

Observation: Were students able to imitate the molecular activity of their object(s) during extension exercise #1 below?

Journal assignment: Some objects feel warm when we touch them and some feel cool. Explain why.

Extension activities

- Have students review the handout from the exploration activity. Divide them into groups of 3-4 each. Explain that each group member will play the role of one molecule. Each group of "molecules" will bounce like real molecules do—either slow or fast—depending on the object they are portraying. Go back to prior learning for examples, such as they would bounce slowly to play the role of carpet and fast to play foil. Let students practice. Move through the groups, assisting them with role assignment and heat source information.

- Help students construct a simple model to demonstrate the molecular action of heat energy. For example, using ping pong balls or empty toilet paper rolls for molecules, construct a mobile from a wire hanger, string, and hanging objects that are tied close together. Hang the mobiles, then move one object to set the others into motion. Have students practice setting the mobiles in motion in different ways—fast with a strong force from the pulled object and slower by using less force.

Subject integration

Social Studies. Based on what students have learned about heat conduction, facilitate a lesson on clothing styles in different areas of the world. Focus on their practical application, e.g., white, cotton shirts are common in tropical countries because white and cotton are poor heat conductors.

Art. Facilitate an art lesson, focusing on colors as good or poor heat conductors.

Resources for teachers

Physics For Every Kid. Janice Van Cleave (1991).

How Does It Feel? Data Sheet

Name(s)

Object	Hot	Warm	Cool
1.			
2.			
3.			
4.			
5.			
6.			

A BUNCH OF HOT AIR

Topic: Thermal dynamics

Learning objectives

Learners will:

1. Gain knowledge of the principles of evaporation and heat.
2. Determine whether water evaporates faster in hot or cold air.

Process skills

○ Building models
○ Categorizing or classifying
● Communicating
● Comparing
● Controlling variables
● Experimenting
● Hypothesizing
○ Inferring
○ Interpreting data
● Measuring
● Observing
○ Ordering
● Predicting
● Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

○ 1
● 2
● 3
○ 4
○ 5
○ 6
○ 7
● 8
○ 9
○ 10
● 11
○ 12

Refer to Appendix F, p. 353, for a description of outcomes.

Time estimates

Setup . . . . 5 minutes
Exploration . . 5-10 minutes
per day for 1-2 weeks
Cleanup . . . . .5 minutes

Key science principles

- Evaporation
- Heat

Materials

3 identical clear containers per group
Rulers
Labels or masking tape for containers
A Bunch of Hot Air data sheets (see p. 216)
Thermometers

Safety tips

- Glass containers should not be used for very young students, and they should be monitored when used with any students.
- When used, glass containers should be located away from hazards (e.g., where they are less likely to be bumped and fall to the floor)

Engagement activity

Note: Students should be somewhat familiar with the different states of matter and the concept of evaporation before beginning this activity. Lead a group discussion about these topics with the question: "Does water evaporate more quickly if it's cold?" Encourage ideas and discussion with questions like, "Why do you think it evaporates faster when it's hot/cold?", "Have you ever seen water evaporate when it's hot/cold?" and "Can you give us an example?" List students' answers on a board or flip chart. Then help them formulate ideas for testing their hypotheses. Select those ideas that involve experimenting with water in hot, cold, and neither hot nor cold places. Finally, review how to use a thermometer, if needed.

Exploration activity

1. Divide students into groups of 2-4 each.
2. Give each group three containers of water.
3. Instruct students to label the containers "hot", "cold" and "neither."

IMPORTANT: Show them how to place their labels on the containers so that the top edge of each label rests exactly on the water line.

4. Have students choose locations for their containers, ensuring that they pick a cold spot, hot spot, and a spot that is neither hot nor cold (e.g., a refrigerator, a sunny window, and teacher's desk, respectively).
5. Have students **carefully** (e.g., no spills) record the temperature and water level of each container daily for 1-2 weeks. You may wish to have them record their conclusions about the measurements along with the readings.
6. Facilitate a group discussion that allows students to share their predictions and observations, and draw conclusions. Ask questions like those listed below in order to help them identify that the water from the hot-air container evaporated the quickest.
   - "What differences did you notice between the containers?"
   - "Did your predictions come true?"
   - "What other ways could we have tested our hypotheses?"
   - "Did this experiment prove or disprove any of our hypotheses? How?"

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge.

A liquid evaporates when molecules escape from its surface. Water vapor evaporates faster in hot air because hot air accepts water vapor more readily than cold air. (Its molecules are farther apart than when the air is cold.)

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. When you observe, you can visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. Which evaporates quicker, water in an Ohio swimming pool in July or water in your fish tank?
2. Which evaporates quicker, water in your bathtub or water on a hot stove?

Observation:

1. Collect and evaluate students' data sheets from the "Bunch of Hot Air" exercise.
2. Assign as homework a similar experiment that uses very common household resources. Have students turn in a data sheet and written predictions, observations and conclusions for a grade.

Journal assignment: Does water evaporate quicker in cold air or hot air? Explain.

Extension activities

- Conduct the same experiment with other liquids, like tea or salt water.
- Conduct the same experiment using different methods to vary the temperatures, like heating over a burner.

Subject integration

Math. The measuring, recording, and subtracting necessary for conducting this experiment make it highly useful for practicing math principles. In addition, constructing graphs of class findings could provide practice of more complex mathematical principles.

Resources for teachers

Water, Step-by-Step Science Series by Carson-Dellosa Publishing

A Bunch of Hot Air Data Sheet

Name(s) ______________________________

Prediction: ______________________________

Date	**Hot air** measurement temperature	**Medium air** measurement temperature	**Cold air** measurement temperature

Conclusions:

PUTTING IT ON: WHAT'S THE WEATHER LIKE?

Topic: Measuring heat

Learning objectives

Students will:

1. Deepen their knowledge of heat as a from of energy.
2. Discover that heat can be measured.

Process skills

● Building models
● Categorizing or classifying
● Communicating
● Comparing
○ Controlling variables
● Experimenting
○ Hypothesizing
○ Inferring
● Interpreting data
● Measuring
● Observing
● Ordering
● Predicting
● Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
● 3
● 4
● 5
● 6
● 7
● 8
● 9
● 10
○ 11
● 12

Refer to Appendix F, p. 353, for a description of outcomes.

Time estimates

Setup	varies
Exploration	1 week or longer
Cleanup	varies

Key science principles

- Absorption
- Thermodynamics
- Conduction
- Temperature
- Measurement
- Heat energy

Materials

Scissors
Doll pattern
On A Hot, Hot Day by Nicole Weiss
World Map
Computer
Colored construction paper
Shirt stencils
Different liquids

Hint: You can make inexpensive and easy patterns by cutting them out of poster board, instead of using store bought-doll patterns.

Safety tips

- Review your science lab rules and remind students to follow these, especially when moving between locations for the experiment.
- Instruct students to use care when handling and using scissors and glass.
- Teach students that in the real world there are some things that are too hot to touch.

Engagement activity

Read *On A Hot, Hot Day* by Nicole Weiss and discuss the differences and similarities in the clothing and locations around the world. You may want to have students locate several places on a globe. Ask students whether the different places have the same temperatures. Explain that today they will be experimenting with different colors and making decisions on what color of clothing they would want to wear if they were living in different places around the world.

Exploration activity

1. Give students different colors of construction paper and a shirt stencil. Ask them to trace and cut out three shirts using various colors.
2. Distribute standard thermometers.
3. Assign a standard length of time (e.g., 15 minutes).
4. Ask students to identify the temperature of the shirts by placing them in the sun and putting the thermometers **under** the shirts. Remind students to use the standard time.
5. Have students create a chart and record the results.
6. Discuss practical, real world ways that heat energy is harnessed for our use, e.g., cooking.

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge.

Heat is a form of energy, and any form of energy (electrical, chemical or mechanical) can be changed into heat energy. Heat energy can also be converted into each of the other forms of energy. Dark colors **absorb** heat better, in part, because they more efficiently absorb the waves of heat that come from the sun's light rays. Light-colored clothing **reflects** most of the heat-making light waves, keeping us cooler on hot days.

Evaluation

Observation allows you to visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Observation:

1. Did students read and record temperatures accurately during the exploration activity?
2. Use the extension activity below for assessment purposes. Have students present the results, and grade the presentations for accuracy. For example, was their doll dressed correctly for their locale?

Journal assignment: Pick one way that you see heat used at home or at school. Explain how it is harnessed as a source of energy.

Extension activity

Have students choose a locale to study. Then provide the necessary materials for them to construct a paper doll and dress it appropriately for the current time of year in that locale. They can research temperatures and related information about their locale on the Internet and in related literature. They can draw and color clothing directly on their dolls to shorten activity time. Or colored construction paper can be used for clothing and poster board for constructing dolls.

Subject integration

Geography. Discuss different types of maps and climates along common map coordinates such as latitude, longitude, meridians, north pole, south pole and equator.

Geography. Discuss weather and temperature patterns in different places on the globe.

Home Economics/Practical Living Skills. Set up a cooking lesson. Discuss safety, measurement, tools, food groups, and heat.

Language Arts. Have students write a report on a topic taken from the Extension activity above.

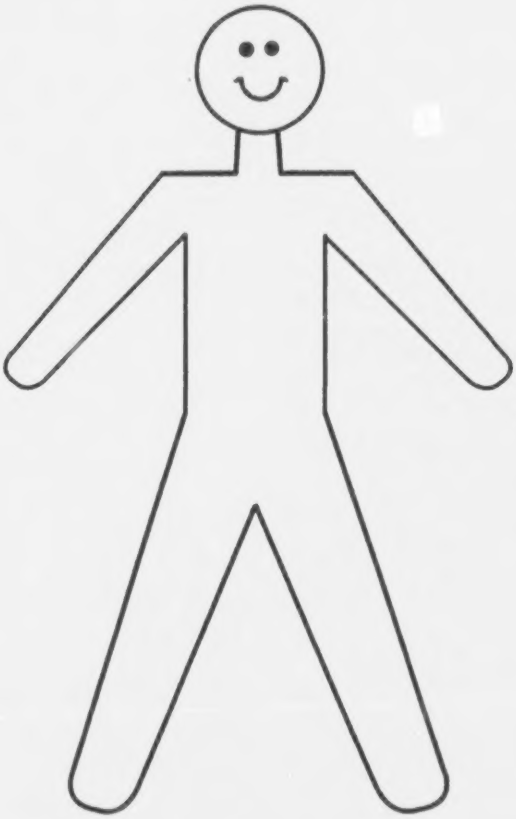
Math and Science. Construct and use a solar oven.

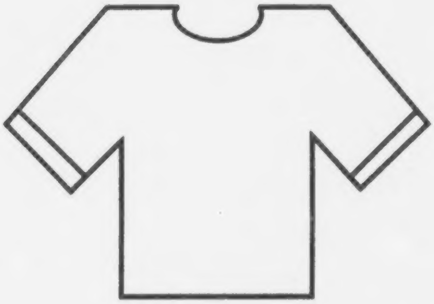
Resources for teachers

202 Science Investigations by Marjorie Frank
Simple Cooking Fun

Resources for students

The Way Things Work-CD ROM
Science Book of Hot and Cold by Neil Ardley
Let's Try It Out . . . Hot and Cold by Simon





Hint: You can also purchase paper doll sets or vinyl sets (e.g., Colorforms™) and create stencils for both dolls and clothing from these. Be sure to provide clothing options for all four seasons.

Putting it on Data Sheet

Name(s) ____________________

Prediction: ____________________

Color of Shirt		Time	
	5 minutes	10 minutes	15 minutes
1.			
2.			
3.			

Conclusions:

KEEP IT COOL

Topic: Ice and insulators

Learning objectives

Students will:

1. Work together to determine if different materials slow the melting rate of ice cubes.
2. Gain knowledge about insulators and insulation.
3. Discuss experiment results with the use of a bar graph.

Process skills

○ Building models
● Categorizing or classifying
● Communicating
● Comparing
○ Controlling variables
● Experimenting
● Hypothesizing
○ Inferring
● Interpreting data
○ Measuring
● Observing
○ Ordering
● Predicting
○ Recognizing relationships
○ Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
○ 3
● 4
○ 5
○ 6
○ 7
● 8
○ 9
○ 10
● 11
○ 12

Refer to Appendix F, p. 353, for a description of outcomes.

Time estimates

Setup. . . . . 10 minutes
Exploration . . . 90 minutes
Cleanup . . . . . . 10 minutes

Key science principles

- Insulation
- Freeze
- Cold
- Melt

Materials

9-ounce, clear plastic cups with a piece of masking tape attached (large enough to print student's or team's name)

Keep It Cool data sheet

Cooler of small (½-inch diameter), blue ice cubes (Note: Use blue food coloring when freezing so the cubes will be easier to see. Larger cubes may be used, but the activity may require more time to complete.)

Clock

Zip-style sandwich or snack bags

Insulators (some options are listed below) (lay them on a table for students to select from):

- Styrofoam packing peanuts
- Aluminum foil
- Fabric scrap
- Plastic bags
- Newspaper
- Shredded newspaper
- Cardboard
- Uncooked rice
- Rubber bands
- Feathers
- Straw
- Sand
- Bubble wrap
- Cotton balls
- Room-temperature liquids such as water, cooking oil, vinegar, and carbonated water

Safety tips

- ✚ Holding an ice cube for an extended period of time may cause discomfort.
- ✚ Puddles from melting ice will make floors slippery. Make sure drips are contained or wiped from the floor immediately.

Hints:

- *The time needed for this activity depends upon the size of ice cubes used. Non-insulated cubes of approximately $^1/_2$" in diameter take about $^1/_2$ hour to melt.*
- *Cover all tables with newspaper to make clean up easier.*

Engagement activity

- Give each learner an ice cube in a clear plastic cup. Ask the following questions:
  - ? " What can you tell me about your ice cube?" (e.g., cold, frozen water, changes back to water, slippery, clear, may have bubbles in it) List students observations on the board or on flip chart paper.
  - ? "What materials do you see on this table that might keep this ice cube from melting?" (e.g., styrofoam, cardboard)
  - ? "Where have you seen those materials used?" (e.g., coolers, cups at fast food restaurants)

  After discussion is complete, have students return their ice cubes to the cooler and collect their cups.

Exploration activity

1. Have each student choose one material to design a container to keep an ice cube from melting.
2. When the container is complete, give everyone an identical ice cube inside a plastic bag to be inserted into their "ice savers".
3. After 30 minutes, have each student remove the plastic bag from the container. Record findings on a class data sheet. Results can be graphed or discussed based on the relative sizes of the ice cubes (or the amount of water found in each plastic bag can be measured).
4. Facilitate a class discussion about the ice savers. Some questions you could ask include:
   - "What materials kept the ice from melting quickly?"
   - "Are any materials similar?" (e.g., Matt and Kathy both used liquids, but Matt used water and Kathy used oil. Which of those cubes melted faster? Answer: the one in water.)
   - "What do you use at home to keep your ice cubes from melting?" (e.g., freezer, cold pack)
   - "If you want to take ice from your home to another place, what do you use? (e.g., cooler)
   - "What is your cooler made from?" (e.g., styrofoam, plastic)
   - "Mike and Sarah used the same materials, but Sarah's cube melted faster. What could have happened?" (e.g., different size cubes, different amounts of insulation, different density of packing material, different room temperatures)
   - "What materials made the best insulators?"

- "If we conduct this same experiment outside today (it's 90 degrees outside), what will happen?" (Answer: The ice will melt quicker, but the insulators will still slow down the melting process.)
- "Why does ice melt in pop?" (Answer: The pop is warmer than the ice.)

5. Results can be graphed, categorized, or discussed based on the relative sizes of the ice cubes (or the amount of water found in each plastic bag can be measured).

NOTE: The World Champion Ice Cube Keeper is David Webster. He kept an ordinary ice cube from melting for sixteen hours in a room at 70 degrees F (from Robert Gardner's Favorite Science Experiments.)

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge.

Some materials, called **insulators** help cold things stay cold. Insulators slow down the speed at which cold things absorb heat. When you put a container of cold water in a warm room, for example, the heat from the room moves into the water. *The cold does not move out of the water, because heat moves from a hot area to a cold area (law of thermodynamics)*. Different types of insulators impact the flow of heat differently—either the heat moves slower or quicker. Insulators also help hot things stay hot.

Evaluation

Questions like those referred to below can be used for testing, homework assignments and similar evaluation techniques. Observation allows you to visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions: Use all or some of the discussion questions listed in the exploration activity to create a quiz or test.

Observation: Have students list the insulators in order of effectiveness. Then instruct them to add others that were not used in the experiment. Have students chart the results on a bar graph and present the graph first to each other for practice, then to teachers and administrators and/or other classes.

Journal assignment: You are a research scientist and your job is to invent a new kind of container to keep things cold. What materials would you use? Explain.

Extension activities

- Tell students that they have been given a cold can of pop on a very hot day. Ask them what they could do to keep the can colder longer? Make a list on the chalk board or chart paper.

  Hint: Possible answers include: keep pop in freezer between drinks, put can in foam holder (show a holder), wrap can with foil, put can into bucket with ice around it, wrap can in newspaper or cloth, pack sawdust or ice around can, make a nest for the can from grass or leaves.

- Read a winter story such as *Little Penquin's Tale*.
- Study other properties of ice, e.g., water expands when it is frozen, ice floats.
- Fill two identical cups with cold water. Place 2 ice cubes in each cup. Cover one finger on one hand with ½ inch of vegetable shortening. Then simultaneously put the shortening-covered finger into one cup of ice water and the same finger (not covered with shortening) from the other hand into the second cup of water. What happened? Using a thermometer to measure the temperature in both cups, confirm the results. Discuss feathers, fur, and fat, and how such things insulate animals in cold temperatures.

Subject integration

Language Arts. Read aloud a story about penguins. Discuss ways animals use insulation to keep warm.

Social Studies. Create a series of lessons about Eskimos, focusing on how they retain heat in their bodies, homes, food and other situations.

Math. Chart results of all or some of your ice experiments on bar graphs, as described in the evaluation section. Discuss the graphs from a mathematical perspective, e.g., math principles used in practical ways, other real-world applications for such principles.

Art. Have students draw a picture of themselves and the way they would dress if they were traveling to Antarctica. Begin this activity with a discussion of Antarctica's environment.

Resources for teachers

Be a Kid Physicist by William Wellnitz. (TAB Books, McGraw-Hill, 1993.)

The Little Scientist: An Activity Lab by Jean Stangl. (TAB Books, McGraw-Hill, 1993.)

Robert Gardner's Favorite Science Experiments by Robert Gardner (Robert Gardner, 1992.)

Science Activities for Students by Willard Jacobson and Abby Bergman (Prentice-Hall, 1983.)

Wonder Science: Insulation, April, 1994; American Chemical Society/American Institute of Physics

Resources for students

Hot and Cold by Allan Fowler. (Students's Press, 1994.)

Hot and Cold by Terry Jennings. (BLA Publishing Limited, 1988.)

Penguins by Jenny Markert. (The Child's World, Inc., 1991.)

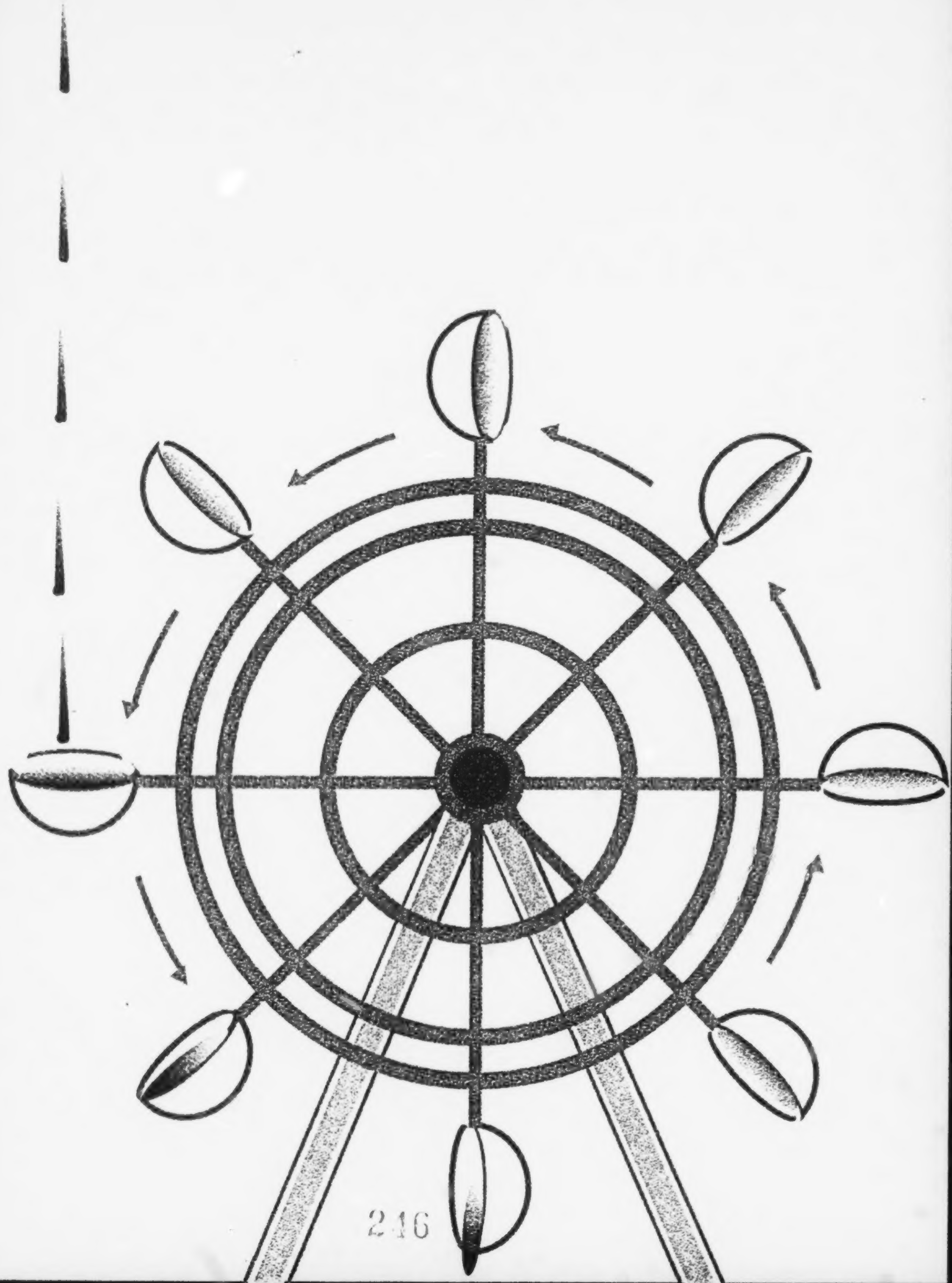
Temperature and You by Betsy and Guilio Maestro. (Lodestar Books, 1990.)

Keep It Cool Data Sheet

Student's Name	Type of Insulator	Good Insulator	Poor Insulator

Notes

245



FUN WITH PHYSICS:

Real-Life Problem Solving for Grades K-3

Exploring Liquids

Learning Activities **Page**

Ready, Set, Float 235

Wave Bottles 243

Goopy Goop 251

Traveling Marble 257

Busy Colors 265

Bubbles Bubbles Everywhere! 273

Squirt Gun Fun 283

NOTE: The learning activities about liquids were placed in their current order because of the sequence in which the scientific principles are introduced and build upon each other. However, the activities can be used in any order—as long as students are provided with the needed scientific background.

LIQUIDS VOCABULARY

Bubble

Buoyancy

Density

Gravity

Flow

Liquid

Mixtures

States of matter

- Solid
- Liquid
- Gas

Surface tension

Water pressure

READY, SET, FLOAT

Topic: Density of solids and liquids

Learning objectives

Students will:

1. Gain a basic knowledge of what causes objects to float or sink in water.
2. Use this knowledge to predict whether items will float or sink.

Process skills

○ Building models
● Categorizing or classifying
● Communicating
○ Comparing
○ Controlling variables
● Experimenting
○ Hypothesizing
○ Inferring
○ Interpreting data
○ Measuring
● Observing
○ Ordering
● Predicting
○ Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
● 3
● 4
○ 5
○ 6
● 7
○ 8
○ 9
○ 10
○ 11
○ 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup . . . . 5 minutes
Exploration . . . 20 minutes
Cleanup . . . . 5 minutes

Key science principles

- Surface tension
- Density
- Buoyancy

Materials

Balloons (1 inflated, 1 to be inflated)

Items that either sink or float (e.g., corks, sponges, buttons, nails, wooden spoons, metal spoons, keys, pencils, crayons, styrofoam packing material, wooden blocks, and/or fruits and vegetables, such as apples, grapes, melons, oranges, green beans, onions)

Container of water (e.g., dish tub, plastic baby tub, clear plastic bucket)

Sink or Float data sheet

Leaf

Markers

Newsprint

Paint smocks

Safety tips

- Wear paint smocks to prevent clothes from getting wet.
- Use paper towels, cloth towels, and newspapers to reduce safety hazards caused by spills.

Engagement activity

Organize a class discussion concerning floating and sinking. Use questions like:

- "What do the words "float" and "sink" mean?" *Hint: Let students find these words and their definitions in a dictionary.*
- "Can you think of some objects that float? that sink?"
- "Do you know why some objects float and some sink?"
- "Do large objects float more easily than small ones?"
- "Does the shape of the object make any difference?"

Hint: Use pictures of objects or have students make drawings to enhance the discussion.

Exploration activity

1. Have students verbally identify each item to be tested.
2. Let each student choose one or two items to test.
3. Either one at a time or in groups, have students predict whether their items will sink or float.
4. Record predictions on a Sink or Float data sheet.
5. Place each item in a tub or bucket of water and observe whether the prediction was correct. Mark the chart accordingly.
6. Have students put items that sink in one pile or container and those that float in another pile or container.
7. Help students categorize objects that sink and those that float into subdivisions (e.g., large or small, heavy or light). *Hint: If fruits and vegetables are used, have students cut them open to look for visual signs that differentiate floaters from sinkers. In most cases, it is evident that floaters have spaces that store air.*
8. Lead students through a discussion of similarities and differences.

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraphs will emerge or teach the concepts through enhancement, exploration or expansion activities.

Liquids exert pressure equally on all sides—even pushing upward on the bottom of an object that is immersed in it. When an object is suspended in water, the pressures on opposite sides cancel each other out. Because pressure increases with depth, the upward force on the bottom of the object will be greater than the downward forces on the top. In other words, there is a net lifting force operating; any object is lighter when in water than it would be if it were out in the air. The existence of such a lifting force is called **buoyancy**.

Because of buoyancy, water tries to support solid objects. It is the **density** of an object that determines if it will float in water or not. Density is the *weight* of an object divided by its *volume*. In other words, if the volume of an item (e.g., apple) is heavier than the volume of water (which is 1 gram per cubic centimeter), the item will float. Conversely, if an item is *lighter that water*, it will float. Therefore, if an object is light for its size, it floats. Lighter objects have lower **density**. Objects that are heavier than water (that is, if volumes were the same), they are more dense that water and will sink.

So you can see that if objects are the **same size** but have **different densities**, one may float while the other sinks. (Note: some objects may float at first, but eventually sink, e.g., sponges. In these cases, the principle of **absorption** is at work. Water is absorbed into the object until the item was more dense than the water—and it sunk.)

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Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. When you observe, you can visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

A big, light object (like a very large leaf) floats because it has ________ density.

A small, heavy object (like a penny) sinks because it has ________ density.

Observation: Let students practice predicting whether objects will sink or float. Monitor their predictions, asking them to explain the reasons for their predictions. Evaluate and record their abilities to apply concepts related to density.

Journal assignment: Explain why an inflated balloon floats while a piece of metal of the same size sinks.

Extension activities

- Let students repeat the exploration activity using different liquids such as cooking oil, milk, or corn syrup. You can substitute different objects, as well. After testing is complete, pour the liquids into one cylinder and watch the layering effect. This layering is also caused by density, i.e., different liquids have different densities and the most dense sink to the bottom while the least dense liquids rise to the top (float). (More about this in the next learning activities.)

- Help students to float different types of woods. *(Hint: Cork or maple will float, mahogany will rise just to the water's surface, and ebony will sink.)*
- Conduct density comparisons with like objects, e.g., a ping-pong ball and a golf ball, a plastic key and a metal key.
- Test solid items that float or sink. Then use clay to form different shapes (e.g., solid ball, bowl-shaped object, flat object). *(Hint: A solid ball will sink but an object with sides will float.)*
- Use candy bars to study the concept of density. *(Hint: Snickers™ and 3 Musketeers™ work well).* Let students test each candy bar and record whether it floats or sinks. When testing is complete, cut the candy bars in half so that students can observe the density differences.
- Help students learn about absorption by including in the exploration activity objects that float at first, but eventually sink (e.g., sponges).

Subject integration

Language Arts. Have students read books like *Curious George Rides A Bike* by H. A. Rey, What Floats by Mary Brewer, and *Why Does It Float?* by C. Arvetis & C. Palmer. Assign a journal entry or theme paper, instructing students to use what they learned in their float testing to discuss the story.

Art and/or **Social Studies**. Conduct a series of lessons around a boating theme. Have students study different types of boats, draw some, and build one. In addition, help students to explore different cultures' use of boats and how each boat serves the needs of the people of that culture.

Resources for teachers

175 Science Experiments to Amuse and Amaze Your Friends by Brenda Walpole. (Random House, 1988.)
Math and Science for Young Children, 2nd Edition by R. Charlesworth & K. Lind. (Delmar Publishers, 1995.)
Science Experiences for the Early Childhood Years, 4th Edition by Jean Harlan. (Merrill Publishing Company, 1988.)
Why? Experiments for the Young Scientist by D. and K. Prochnow. (1993)
"Water Travel" from *The Way Things Work*. (CD-ROM, Houghton Mifflin.)
Liquids in Action by Peter Mellett & Jane Rossiter. (Franklin Watts, 1992.)
Solids, Liquids, Gas from the Discovery Works Series. (Video, Silver Burdette Ginn Science, 1996.)

Resources for students

Curious George Rides A Bike by H. A. Rey. (Scholastic Book Services, 1973.)
What Floats? by Mary Brewer. (Children's Press, 1976.)
Why Does It Float? by C. Arvetis & C. Palmer. (Rand McNally, 1983.)

Sink or Float Data Sheet

Name(s) ______________________________

____

Directions:

1. List or draw the items you'll be testing in the first column.
2. Predict whether an object will sink or float. Record your prediction.
3. Test the object listed ; observe whether the object floats or sinks. Record your observations by putting an "X" in either the "sinks" or the "floats" column.

Items to Test	Prediction	Sinks	Floats

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WAVE BOTTLES

Topic: Students will construct an explore wave bottles to learn about principles of density and solubility.

Learning objectives

Students will:

1. Construct a wave bottle.
2. Experiment with mixing different liquids.

Process skills

- ● Building models
- ○ Categorizing or classifying
- ● Communicating
- ○ Comparing
- ○ Controlling variables
- ● Experimenting
- ○ Hypothesizing
- ○ Inferring
- ○ Interpreting data
- ● Measuring
- ● Observing
- ○ Ordering
- ● Predicting
- ○ Recognizing relationships
- ● Recording

Ohio 4th-grade science proficiency outcomes

- ○ 1
- ● 2
- ● 3
- ○ 4
- ○ 5
- ● 6
- ● 7
- ● 8
- ● 9
- ○ 10
- ● 11
- ● 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup	5-10 minutes
Exploration	15-20 minutes
Cleanup	5 minutes

Key science principle

- Density
- Solubility

Materials

Clear plastic containers with lids (e.g., 16-ounce plastic soda bottles with twist caps)

Water

Baby oil or vegetable oil

Food coloring

Masking tape

Safety tips

- Use vegetable oil with young students to reduce hazards if swallowed.

Engagement activity (optional)

Discuss predicting, observing, and recording and their importance in scientific experiments. Then provide the opportunity for students to practice these functions by taking the steps described below—using a measuring cup, water, and a plastic container. In this activity, groups of 2-4 students will measure specified amounts of water into their containers (e.g., ½ cup ⅓ cup, ⅔ cup, ¾ cup) by doing the following:

1. Instruct each team of students to fill a container with water.
2. Then have them remove the water by pouring it into a measuring cup—keeping track of the total amount of water that has been removed.
3. Help students total the amount of water that they measured from the container.
4. Help students calculate ½ of the total amount of water that their container holds (e.g., ½ of a 2-cup container is 1 cup).
5. Instruct students to fill their containers ½ full with water.

6. Then help students calculate $^2/_3$ of the total amount of water that their container holds (e.g., $^2/_3$ of a 3-cup container is 2 cups).
7. Instruct students to fill their containers $^2/_3$ full with water and mark the $^2/_3$ level by placing a piece of masking tape at the water line. *Hint: These containers, with the $^2/_3$ marking, can be used in the exploration activity.*

Exploration activity

1. While distributing the rest of the materials, explain to students that the containers they created in the engagement activity are called "wave bottles."
2. Instruct each student (or group, if working in teams) to fill the wave bottles $^2/_3$ full with water.
3. Have students add a few drops of food coloring and observe what happens.
4. Give students time to record their observations with words or drawings.
5. Explain that they will add oil to the wave bottles next.
6. Ask them to predict what they think will happen when oil is added to the container and record their prediction.
7. Instruct students to add enough oil to their bottles to make them almost full, then observe and record what happens.
8. Have students place lids/caps tightly on top of the bottles. (Some students may require assistance.)
9. Encourage students to explore what happens when they move the bottles (e.g., shake, turn upside down, roll).
10. Remind students to record their observations after each test.

11. Once students have had plenty of time to explore, conduct a group discussion with the following questions:
    - "What happened when food coloring was added to the water?"
    - "What did you observe when the second liquid (oil) was added?"
    - "What did you predict would happen when the second liquid was added?"
    - "Compare the results against your predictions. What do you find?"
    - "What happened when you moved or shook the bottle?"
12. Help students conclude that the two liquids will always remain separate with questions like:
    - "How many different liquids do you observe in your bottle right now?"
    - "What happened to the different liquids when you shook your bottle?"
    - "What happened to the different liquids when you kept your bottle still?"

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge or teach the concepts through enhancement, exploration or expansion activities.

Density and solubility affect whether or not liquids mix together. Liquids of different density remain separate (e.g., oil and water, oil and alcohol, water and alcohol). Furthermore, liquids that are **insoluble** will not mix together. Liquids that are **soluble** will combine. For example, oil is insoluble (does not dissolve) in water. Liquid food coloring *does* dissolve in water, so it is soluble.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. When you observe students, you can visually assess their learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. Do oil and water mix?
2. Is oil soluble or insoluble?
3. If a liquid mixes with water, it is called ________.

Observation: Review students' recorded predictions, observations and conclusions. Assess whether their conclusions indicate an understanding of the concepts of soluble and insoluble. *(Hint: Students should conclude that the oil and water will not mix together.)*

Journal assignment: Think about two liquids you have combined in the past. Name the liquids and describe what happened. Explain whether they were soluble or insoluble and why.

Extension activities

- Allow students to experiment with other mixtures in their wave bottles such as water and rubbing alcohol, vegetable oil and rubbing alcohol, water an corn syrup, vegetable oil and corn syrup, and vinegar and oil. *(Hint: With younger students, you may wish to avoid using alcohol.)*
- Add small objects (e.g., glitter, sequin, beads) to wave bottles. Have students observe what happens when the objects travel through liquids of varying densities.
- Integrate students' knowledge about density by introducing some "mystery" liquids. Ask them to predict whether each liquid will mix with water by studying the density of each (e.g., thinner liquids are more likely to mix than thicker ones). After testing, let students make guesses to identify mystery liquids.

Subject integration

Math. Making wave bottles involves measuring. Help students relate the math concepts of measuring and fractions to the activities involved in making their bottles. Allow them to practice working with fractions by exploring with their bottles. (See engagement activity.)

Social Studies. Display a wave bottle with oil and water combined. Explain that this is what happens during oil spills in the ocean. Help students study such environmental disasters, e.g., the impact on wildlife and human beings, how long the destruction lasts. You may want to ask a college student or professor in the field of environmental science to make a presentation to the class.

Resources for teachers

What Will Happen If…Young Children and the Scientific Method. (Educational Equity Concepts, Inc., 1990)

Notes

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GOOPY GOOP

Topic: Students will explore liquid matter as it goes through phases or states

Learning objectives

Students will:

1. Create a liquid substance called "goop."
2. Change goop (e.g., different thicknesses) by altering the ingredients.
3. Experience liquid matter as it goes through different phases.

Process skills

○ Building models
● Categorizing or classifying
● Communicating
● Comparing
○ Controlling variables
● Experimenting
○ Hypothesizing
○ Inferring
○ Interpreting data
● Measuring
● Observing
● Ordering
○ Predicting
● Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
○ 3
○ 4
○ 5
○ 6
○ 7
● 8
● 9
○ 10
● 11
○ 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup .... 5 minutes
Exploration .... 30 minutes
Cleanup ..... 5-10 minutes

Key science principles

- States of matter
- Mixture properties

Materials

Plastic bowls

Elmer's™-type glue

Mixing spoons

Stay-Flo™ liquid starch

Food coloring

Plastic trays (optional)

Safety tips

- Keep all materials on a table surface or plastic tray.
- Wear paint smocks.

Engagement activity

Demonstrate the process of making a batch of goop by mixing 2 parts Elmer's™-type school glue to 1 part Stay-Flo™ liquid starch. Let students help (e.g., assign a different student to add each ingredient, let students take turns stirring). You may wish to add food coloring to create desired color. Continue to stir ingredients. *(Hint: Goop looks like cottage cheese until enough mixing brings it to a uniform consistency.) Explain to students that they will use the goop to learn more about liquids.*

Exploration activity

1. Divide the batch of goop created in the engagement activity into portions for each student.
2. Allow them to explore the feeling of the goop.
3. In a discussion, ask students to describe the goop's temperature, texture, and consistency.
4. Add glue to each portion and discuss what happens. (Answer: Goop becomes runnier.)
5. Add liquid starch to each portion and discuss what happens. (Answer: Goop becomes stiffer.)
6. Freeze some goop and record how long it takes to freeze.
7. Thaw it and record the time needed.
8. Help students discuss the changes (or phases) the goop went through and why. *(Hint: Create discussion questions from the information contained in the explanation section below.)*

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge or teach the concepts through enhancement, exploration, or extension activities.

Liquids can change forms or states when they are:

- Combined with other materials (e.g., adding flour to water)
- Exposed to environmental changes (e.g., heating or freezing)

The exploration and extension activities help students experience this first hand.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. When you observe students, you can visually assess their learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. What happened to the goop when more glue was added?
2. What happened to the goop when more starch was added?
3. Does goop take more or less time to freeze than water?
4. Draw a picture that shows how a liquid changes forms.

Observation: Conduct the first extension activity. Review students' conclusions. Assess and record whether students demonstrate an understanding of the properties and States of matter.

Journal assignment: Describe how you made "goopy goop" and what it felt like.

Extension activities

- Freeze different liquids (e.g., water, oil, starch, milk, juice) in ice cube trays. Have students predict how long each will take to freeze. Instruct them to record their predictions and the actual times. Thaw the liquids, recording predictions and results. Compare the results for each liquid to determine which took the most time, least time, and did not freeze. Help students explain the results.

- Conduct a “Crystal Bubbles” activity. Read *Bubble Bubble* by Mercer Mayer (1993). Take a round bubble blower and soap mixture outside when it is very, very cold and there is no wind. Gently blow a large bubble. Keep the bubble very still (e.g., do not let the wind blow it away). If it is very cold, the thin bubble should begin to freeze as you watch. Tiny crystals should form over the surface of the bubble. As you watch, it should freeze completely, forming a tiny “crystal ball.” Help students discuss the scientific principles that caused the crystal ball to form.
- Have students create and explore with a different type of goop. For each group of students, mix ½ cup of cornstarch with ⅛ - ¼ cup of water in a container such as a pie pan. If desired, food coloring can be added. *(Hint: This goop responds differently than the glue mixture. It will spontaneously change from a solid to a liquid state—right before your eyes!)* Ask questions like those that follow:
  - “How does it feel when you squeeze it?”
  - “What happens when you roll it in a ball?”
  - “What happens when you roll it into a snake shape?”
  - “What happens when you stop squeezing and just let it lay in your hands?”

Subject integration

Math.

- Encourage students to count aloud as they stir jello or drink mixes. Have them record how long it takes to fully combine the liquids and for the liquid in the jello to move into its solid phase.
- Have students weigh things in wet and dry states. Help them conclude and record which weighs more and less.
- Provide students with measuring cups, containers of different sizes, and water. Let them choose a measuring cup (any size) and two containers (one small and one larger). Have them compare how many times they need to fill the measuring cup in order to fill the first container against how many refills it takes to fill the other one. Have them graph their findings.

Language Arts. Read *The Snowy Day* by Ezra Jack Keats. (New York: Viking Press, 1962.) Help students discuss the book in the context of the knowledge gained during their goop experiments.

Resources for teachers

Math and Science for Young Children, 2nd Edition by R. Charlesworth & K. Lind. (Delmar Publishers, 1995.)

Science Experiences for the Early Childhood Years, 4th Edition by Jean Harlan. (Merrill Publishing Company, 1988.)

THE TRAVELING MARBLE

Topic: Gravity and density of liquids

Learning objective

Students will discover principles of gravity and density as it relates to liquids.

Process skills

- ○ Building models
- ○ Categorizing or classifying
- ● Communicating
- ● Comparing
- ● Controlling variables
- ● Experimenting
- ● Hypothesizing
- ○ Inferring
- ○ Interpreting data
- ● Measuring
- ● Observing
- ○ Ordering
- ● Predicting
- ○ Recognizing relationships
- ● Recording

Ohio 4th-grade science proficiency outcomes

- ○ 1
- ● 2
- ○ 3
- ● 4
- ○ 5
- ○ 6
- ○ 7
- ● 8
- ○ 9
- ○ 10
- ○ 11
- ● 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup .... 10 minutes
Exploration .... 30 minutes
Cleanup ...... 10 minutes

Key science principles

- Gravity
- Density

Materials

Identical clear plastic bottles with lids or caps

Identical marbles

Water

Light corn syrup

Clear glue

Stopwatches (If not available, see the option described in exploration step 5c below.)

The Traveling Marble data sheets

Safety tips

- Remind students to never put marbles or other small objects in their mouths. Monitor students closely during the experiments to avoid choking hazards.

Exploration activity

1. Prepare bottles in advance by placing a marble in each.
2. For each team, fill bottles—one with each liquid: clear glue, corn syrup, water, and air (i.e. empty). Place caps tightly on all bottles.
3. Label each bottle with a number and its contents. *(Hint: You may wish to use symbols or pictures rather than words for very young students.)*
4. Divide students into teams of 2-4. Assign roles of recorder, reporter, timer, and bottle turner.

5. Give students time to experiment with each of the 4 bottles by doing the following:
    a. Have students turn each bottle upside down until the marble touches the lid, then place them upright to observe the marble traveling back to the bottom of the bottle. *(Hint: The bottles can be passed from team to team.)*
    b. Have students predict how long it will take for each marble to fall from the top to the bottom of each bottle.
    c. Instruct students to **time** the marbles with the stopwatch and record how long it takes for the marble in each bottle to fall through each of the four liquids. *(Hint: If using stopwatches is too difficult for students, or if they are not available, have them order the bottles by fastest falling marble to slowest.)*
    d. Instruct students to observe and record additional information, including the sound of each marble, any bubbles that are made, and the way each liquid moves.
6. Circulate among the groups, encouraging predictions and asking leading questions to keep the activity moving and enhance learning.

7. After all groups are finished, lead a class discussion with questions such as:
    - "In which bottle did the marble move the fastest/slowest?"
    - "Which made a sound?" and "What kind of sound did it make?" and "Was the sound in each bottle the same or different?"
    - "What other observations did you make, e.g., bubbles, movement of the liquid?"
    - "Which of your predictions were accurate?
    - "How did the liquids react differently?"
    - "What activities were the same in all four bottles?"
    - "Why did the marble fall slower/faster in different bottles?" *(Hint: Be sure to integrate the concepts of gravity and density into the discussion.)*

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge or teach the concepts through enhancement, exploration or expansion activities.

When the bottle is turned upside down, the object (marble) falls to the bottom of the bottle. This is caused by **gravity**—the pull of the earth on objects that are close to it.

The speed of the marble is influenced by the thickness, or **density**, of the liquid through which it is falling. Liquids like corn syrup are thicker, so the marble travels slowly. **The greater the density, the slower the fall.** Water is less dense than corn syrup, so the marble falls more quickly through water than it does through corn syrup.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. When you observe students, you can visually assess their learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. What is density?
2. Name a liquid that has very low and one that has a high density.
3. What does gravity do?

Observation: Observe students during the experiment and group discussion to assess how well they understand the concepts of gravity and density. Review their data sheets, as well. Determine whether their understanding of the concepts presented was demonstrated by their predictions and conclusions.

Journal assignment: Pretend you are a scuba diver swimming in a sea of syrup. Describe your adventure (e.g., ease of movement, visibility, whether you sink or float).

Extension activities

- Continue the exploration activity by adding to or varying the objects in the bottles (e.g., screws, paper clips, safety pins, and buttons).
- Further expand the exploration activity by adding more bottles containing other liquids (e.g., milk, oil, vinegar, salt water).

- Create wave bottles (see Wave Bottles learning activity, pp. 243-249) containing 3 liquids: water, oil, and syrup. Have students examine several objects to be dropped in their wave bottles and predict the falling time for each. Then instruct students to drop objects in one at a time, recording the actual falling time after each test.

Subject integration

Math. Have students practice math skills by graphing their findings for the exploration and/or extension activities.

Resources for teachers

Water from the Step by Step Science Series. (Carson-Dellosa Publishing Company, Inc.)

What Will Happen If...Young Children and the Scientific Method. (Educational Equity Concepts, Inc., 1990.)

The Traveling Marble Data Sheet

Name(s): ______________________________

____

Bottle	Prediction	Falling Time	Observations
1. Water			
2. Clear glue			
3. Air			
4. Corn syrup			
5.			
6.			

Conclusions:

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Notes

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BUSY COLORS

Topic: Properties of liquids

Learning objective

Through scientific observation, students will gather knowledge about the properties of various liquids by adding food coloring to 4 liquids and observing similarities and differences.

Process skills

○ Building models
○ Categorizing or classifying
● Communicating
● Comparing
○ Controlling variables
● Experimenting
○ Hypothesizing
○ Inferring
○ Interpreting data
○ Measuring
● Observing
○ Ordering
● Predicting
○ Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

○ 1
● 2
● 3
○ 4
○ 5
● 6
● 7
● 8
● 9
○ 10
● 11
● 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup . . . . .15 minutes
Exploration . . . . 30 minutes
Cleanup . . . . . . .10 minutes

Key science principle

- Properties of liquids

Materials

Food coloring (or food coloring paste, which is available from cake supply stores)

Water

Salt

Soda water

Sugar

Clear plastic cups

Busy Colors data sheets

Crayons that match the colors of the food coloring

A picture designed to improve powers of observation, either copied for students or made into an overhead transparency (available from teacher supply stores and catalogs) If unavailable, a magazine photograph that includes a lot of people and/or action can be substituted.

Safety tips

- Discuss with students the potential risks of eating any of the materials in this experiment.
- Provide paper or cloth towels and instruct students to clean up any spills immediately to avoid falls.

Engagement activity

Help students become aware of the process of scientific observation by doing the following:

1. Distribute or project on an overhead a picture designed to improve powers of observation (see the materials list above).
2. Let students study it for several minutes.
3. Then collect the pictures (or turn off the overhead projector) and have students answer questions about what they observed in the picture.
4. Redistribute the pictures (or turn on the overhead projector) and let students recognize how many things they missed or remembered inaccurately.
5. Ask students a different set of questions about the picture. Allow them to handle each question one at a time and observe the picture to answer it.
6. Explain that the second observation method is the type used when conducting experiments. Help them conclude that it is the **more accurate** of the two methods and that's why scientists use it. Finally, help them conclude that they will need to use this "observe and record one item at a time" process in the exploration activity.

Exploration activity

1. Create exploration areas for each student or team of students by filling 4 clear plastic cups as follows:

    #1 water

    #2 salt water

    #3 soda water

    #4 sugar water

    Label the cups with their **numbers only**.

2. Ask students to carefully observe the cups and liquids. Help them discuss any **differences** and **similarities** between the liquids. Explain that they will be experimenting with different liquids and colors, and recording their observations. Stress the importance of recording immediately after observation to ensure accuracy.
3. Demonstrate the process for this experiment by describing what you'll be doing next and then asking students to make predictions about what they think they'll observe. After predictions are made, put a few drops of food coloring into glass #1 (water) and ask a student to record the observation. *(Hint: Younger students may need to conduct the demonstration themselves with a "practice" glass if they are not familiar with using food coloring.)*
4. Instruct the class to experiment with cup #1 together.
5. Allow students to explore the other liquids at their own pace by predicting, adding food coloring, and observing what happens. (Hint: Teachers may want to distribute one cup at a time to prevent spills and inaccurate conclusions.)
6. Circulate, encouraging students to **predict** and **compare**. Remind them to record their observations immediately.
7. Lead a group discussion by asking questions such as:
    - "What kind of predictions did you make?"
    - "Did your predictions change for each cup?"
    - "Did actual results match your predictions?"
    - "Did anything happen that was the same in every liquid?"
    - "What things happened that were different in each liquid?"
8. Help students compare the way the food coloring moved in each cup.

9. Help students to conclude that each cup contains a different liquid. Ask them to guess the identity of each. *(Hint: If students struggle to correctly identify one or more liquids, reveal the contents of the cups through a guessing game or prompts.)*

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge or teach the concepts through enhancement, exploration or expansion activities.

The food coloring reacted differently in each liquid because the each liquid has different properties. The most prominent property difference is **density**. See explanations in previous Exploring Liquids learning activities for further details.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. Observation allows you to visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. Why didn't the food coloring act the same in all four liquids we tested?
2. Which liquid had the most density? Explain.

Observation:

1. Assess students' levels of knowledge by collecting and reviewing their data sheets.
2. Give students a mystery liquid. Ask them to explain its properties (e.g., density) and to identify the liquid. Use their explanations to assess knowledge gained.

Journal assignment: Explain how the food coloring moved differently in each cup and how its movement can help you identify a liquid.

Extension activities

- Continue the exploration activity by adding other liquids such as vinegar, oil, apple juice, and whole milk. Instruct students to continue testing, remembering to record predictions and observations. Discuss the results as a class. (Note: whole milk causes drops of food coloring to look like star bursts on the surface of the liquid.)
- After cleanup from the exploration activity, present a mystery liquid. *(Hint: Choose one of the four liquids used in the activity.)* Have students identify the liquid, letting them refer to their data sheets for help.

Subject integration

Language Arts. Have students to write a story about their favorite liquid substance. Explain that it can be a fiction or non-fiction story and follow any path they choose. The only rules are:

- they must include a prediction of how their liquids will react to food coloring and why
- stories must be fun and/or interesting

Resources for teachers

Liquid Explorations. (Lawrence Hall of Science, GEMS Teacher's Guide.)

Resources for students

Color Dance by Ann Jonas.

Magic School Bus Inside a Hurricane by Johanna Cole.

Magic School Bus At the Water Works by Johanna Cole.

Water by Frank Asch.

Drip Drop by Donald Carrick.

Busy Colors Data Sheet

Name(s) ____________________

Liquid	Prediction	Observation	Name of Liquid
1			
2			
3			
4			

Conclusions:

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BUBBLES BUBBLES EVERYWHERE!

Topic: Characteristics of bubbles

Learning objectives

Students will:

1. Explore different ways in which bubbles can be made.
2. Gain an understanding of the properties of bubbles.

Process skills

○ Building models
● Categorizing or classifying
● Communicating
● Comparing
○ Controlling variables
● Experimenting
○ Hypothesizing
○ Inferring
○ Interpreting data
○ Measuring
● Observing
○ Ordering
● Predicting
○ Recognizing relationships
○ Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
● 3
○ 4
○ 5
○ 6
● 7
○ 8
● 9
○ 10
○ 11
○ 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup . . . . . . 5-10 minutes
Exploration .20-40 minutes
Cleanup . . . . 5-10 minutes

Key science principle

- Surface tension

Materials

Bubble solution (In a bucket, mix 1 cup of Joy® or Dawn® dishwashing liquid with 10 cups of cold or luke-warm water. If available, add 3-4 tablespoons of glycerine, which is inexpensive and available from drug stores.)

Containers for students' bubble solution (e.g., dish-washing pans, cake pans, bowls)

Bubble-making "tools" such as:

> protractors, large paper clips, plastic six-pack holders, berry containers, toilet paper rolls, paper towel rolls, string, rubber bands, spools, paper cups, metal washers, springs, flower pots, food strainers and colanders, pieces of window screen, twistie ties, slotted spoons, plastic tubing of different lengths and sizes, strips of heavy paper, small zip-type bags, small paper plates, medicine droppers, meat basters, aluminum foil (Note: Students' hands can also be used to create bubbles.)

Newspaper (to cover tables with)

Plastic plates (like paper plates, but plastic; dinner size)

Straws

Flip chart paper and markers

Squeegie (for clean up)

Safety tips

- Remind students not to put soap or materials with soap on them in eyes or mouths.
- During the exploration activity, encourage students to not put their mouths directly on their bubble-blowing "tools." Have them blow from a few inches away from the object or wave it through the air.

✚ Younger students may repeatedly suck on their bubble-blowing straws—getting bubble solution in their mouths. To avoid getting soapy solution in their mouths, teachers can cut a small, diamond-shaped hole about an inch from the end of the straw by making 2 snips with a scissors. The hole won't interfere with bubble blowing, but when students suck on them, only air will reach their mouths.

Clean-up suggestions:

- Sponges and rags don't work well when cleaning bubble solution. A squeegie works best to clear soapy solution off of surfaces.
- If using metal items as "tools," rinse and dry them promptly or they'll rust.

Engagement activity

Help students gain a general understanding of the characteristics of bubbles by doing the following:

1. Give each student a plastic plate and a straw. Pour bubble solution in each plate so that it is about $^3/_4$ inch deep.

2. Challenge students to use their straw to learn whatever they can about bubbles by doing some or all of the following:
    - Blow bubbles of different sizes on your plate.
    - Make as many bubbles as you can on your plate.
    - Make the biggest bubble you can on your plate.
    - Make a bubble within a bubble on your plate.
    - Blow a cluster of bubbles on your plate. Are there honeycomb-shaped (i.e., hexagonal) bubbles? What else do you know that is shaped like a honeycomb?
    - Observe your bubbles: What do they look like? Does their appearance change over time? What color are they?
    - Does the color of your plate change the color of your bubbles?
    - What will happen if you touch your bubble with a dry finger? A wet finger?
3. Once students have had a chance to explore, hold a class discussion. Ask them to share words that describe bubbles. Help students compare their experiences and observations with those of classmates. Record observations and conclusions on chart paper.

    Hint: The exploration activities can also be done by blowing bubbles directly on tables.

Exploration activity

Guide students through an exploration during which they can make observations about the characteristics of bubbles and the "tools" that can be used to blow them.

1. On a newspaper-covered table, give each team of 4 students a pan containing _-inch or more of bubble solution and a variety of "tools" with which to blow bubbles. (See the materials list for tool ideas.)
2. Have them choose a "tool" and predict whether it will blow a big bubble, a small bubble, or no bubble at all. Then have them test their prediction. They should test each of the tools at their table in this way.

   Note: Because this activity is wet and soapy, we have not provided a data sheet for students to use during this activity. Predictions and conclusions will be discussed at the end of the exploration.
3. Once students have had enough time to explore, hold a class discussion. On chart paper, list the tools that were tested, students' predictions, and then the results (i.e., whether the tools made big bubbles, small bubbles, or no bubbles at all). Help students draw conclusions about bubbles and the tools that can create them.
4. Have the class examine the non-bubble blowing "tools." Ask them to consider how they could be made into bubble-blowing tools. If possible, have them take the actions that they suggest and then test out their modified bubble-blowing "tools." *(Hint: this is a good opportunity to point out the steps involved in the scientific method.)*

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge or teach the concepts through enhancement, exploration or expansion activities.

A bubble is a thin skin of liquid that surrounds a gas. This thin skin (i.e., soap film) has elastic qualities; it can stretch. The soap film is composed of molecules of water and soap. The gas that fills bubbles is carbon dioxide and other gases that are exhaled by the bubble-blowing person. The liquid and gas are separated by a **surface**—the soap film.

Surface tension is the reason why the combination of soap and water can produce bubbles. Surface tension is caused by the molecular attraction that a substance has to itself. (In the case of water molecules, which have positive electrical charges on one end and negative charges on the other, there are "attachments" or "weak bonds." These bonds with other water molecules, at the surface, are what causes the surface tension. The surface tension of water is always high. (Examples of surface tension include a bug that is able to glide across the surface of water, or water that swells out over the edge of a cup or the top of a penny.) When soap is added to water, the water molecules are pushed farther apart and the surface tension is **lessened**.

You can blow a bubble with just about anything that has a hole in it. The size of the hole will generally predict the size of the bubble. However, the size of the bubble can be influenced by whether the bubble is blown slowly and gently or quickly. In addition, the shape of the bubble can be affected by the shape of the bubble-blowing tool.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. When you observe students, you can visually assess their learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. What is the same about the tools that make bubbles? big bubbles? small bubbles?
2. Can you turn a non-bubble blower into a bubble-blowing tool?

Observation: During the engagement and exploration activities, observe students as they hypothesize, predict, and draw conclusions about bubbles. Ask them questions about their process as they do exploration.

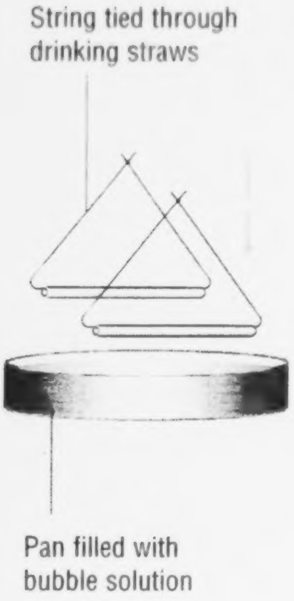
Journal assignment: Pretend you are a bubble. Write a story about what it feels like to be a bubble.

Extension activities

Help students do more in-depth exploration of bubbles by doing some of the following:

- Have students make bubbles from objects of different shapes and experiment with ways in which bubbles can change shapes.

Bubble Window


String tied through drinking straws
Pan filled with bubble solution

- Show students how to make a bubble window from string that is 3-4 times the length of a drinking straw and 2 straws. Have them tie the string through the straws. When they hold the straws parallel to each other and pull them apart, they've got a collapsible bubble loop. To make bubbles, have each student put their bubble window into the bubble solution and then carefully lift it up and pull it back toward them. The trick is in flipping the frame up or down to break off a bubble.
- Make huge bubbles that will surround a student by putting bubble solution in a child's swimming pool, putting a hula hoop™ in the pool. With the student standing on a crate in the center of the pool, pull the hula hoop™ up—around the student.
- Have each student make bubble prints by placing a plastic cup on top of white paper and then **gently** blowing bubbles into plastic cups that contain bubble solution and a small amount of food coloring. The bubbles will flow over the rim of the cup and fall onto the paper. Keep blowing until there is a big pile of bubbles on the paper! Then lift the cup. Within 30 minutes, the bubbles will have burst and a beautiful bubble print will remain on the paper. (Another option is to omit the food coloring from the cup and to quickly place a few drops of food coloring or poster paint on the middle of the mound of bubbles with an eye dropper. The colors will be brighter and multiple colors can be used.)
- Have students build a bubble-blowing contraption that is a combination of some of their bubble-blowing "tools." This learning activity would build on the simple machines activities, too.

- See Appendix B, pp. 293 to 314, for more books that contain additional bubble activities.

Subject integration

Math and **Art**. Have students make bubble prints (as described in the extensions section of this learning activity). Then have them use rulers to measure the size of their bubbles. Make a chart or graph of their measurements and those of class members.

Math. Have students blow large bubbles with a straw on a table top. Have them measure the height and width of the bubbles with rulers or plastic unifix cubes. They can chart or graph their measurements.

Resources for teachers

Bubbles by Bernie Zubrowski. A Children's Museum Activity Book. (Little Brown & Co., 1979.)

Bubble Festival, a GEMS Teacher's Guide for Presenting Bubble Activities in a Learning Station Format. (Lawrence Hall of Science, 1994.)

Liquid Magic by Philip Watson.

Water K-3 by Carson Dellosa. (CD-ROM 7298.)

Resources for students

Monster Bubbles by Dennis Nolan. (Prentice-Hall, 1976.)

Bubble Bubble by Mercer Mayer (Parent's Magazine Press, 1973)

The Magic Bubble Trip by Ingrid and Dieter Schubert. (Kane-Miller Book Publ., 1981)

Splash! All About Baths by Susan Kovacs Buxbaum and Rita Golden Gleman. (Little, Brown, & Co., 1987.)

Notes

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SQUIRT GUN FUN

Note: Garden sprayers may be substituted for squirt guns in this learning activity.

Topic: Water pressure and flow of liquids

Learning objective

Students will gain knowledge concerning pressure, flow, and distance as they relate to liquids.

Process skills

○ Building models
● Categorizing or classifying
● Communicating
● Comparing
○ Controlling variables
● Experimenting
○ Hypothesizing
○ Inferring
○ Interpreting data
○ Measuring
● Observing
○ Ordering
● Predicting
○ Recognizing relationships
● Recording

Ohio 4th-grade science proficiency outcomes

● 1
● 2
● 3
○ 4
● 5
● 6
○ 7
● 8
● 9
○ 10
○ 11
○ 12

Refer to Appendix F, p. 353, for a description of outcomes.

Estimated time

Setup	5 minutes
Exploration	30 minutes
Cleanup	5 minutes

Key science principles

- Pressure
- Motion
- Flow

Materials

Squirt guns of various types (include simple and super soaker models)

NOTE: If squirt guns are not permitted, substitute garden sprayers.

Newsprint

Markers

Water

Paint smocks

String (and/or other tools for measuring)

Squirt Gun Testing data sheets

Safety tips

- Wear paint smocks to prevent clothes from getting wet.
- Review water safety rules with students (e.g., squirting water in the eyes can permanently damage vision, water on floor surfaces can cause slips or painful falls).

Engagement activity

Display two squirt guns—a simple one and a super soaker. Ask students to identify the similarities and differences between the two, including how each is made, how each works, and how each shoots. List the similarities and differences on a chart.

Exploration activity

1. Label a variety of squirt guns with consecutive numbers.
2. Facilitate a discussion of the terms "pressure" and "flow" with questions like:
    - "What do these words mean?" *(Hint: Give examples of each, i.e., push your hand on top of a table to demonstrate pressure and turn on a water faucet to demonstrate flow.)*
    - "What makes a squirt gun squirt?" or "What makes water come out of a squirt gun?"
3. Divide students into teams of approximately 6 each.
4. If appropriate, assign roles of squirter(s), measurer(s), recorder, and reporter.
5. Provide one set of squirt guns for each team. Do **not** include super soakers in the squirt gun sets; these will be used later.
6. Fill each squirt gun with water or have students fill them.
7. Have students predict which gun will squirt the farthest and provide the logic behind their predictions. Facilitate predictions so that students recognize the need to determine how to measure the distance. After they choose an appropriate method, provide the necessary tools.
8. Instruct students to test each gun and record their observations. *(Hint: You may wish to conduct the testing as a class with younger or more active students.)*
9. When testing is complete, distribute the super soakers.
10. Demonstrate how to pump air into the super soaker, counting strokes.
11. Have students repeat steps 7 and 8 with their super soakers.

12. Help students discuss their observations and draw conclusions from their experiments.
13. Lead the class in experimenting with the super soaker, i.e., pumping different amounts of air into the super soaker, predicting and recording findings. Discuss these results, too.

Explanation

Following exploration, help students to verbalize what they learned. Facilitate a class discussion so that the concepts explained in the next paragraph will emerge or teach the concepts through enhancement, exploration or expansion activities.

The greater the amount of pressure exerted on the water, the greater the distance the water will travel. In the simpler models, pressure is exerted manually. In the super soaker models, pressure is generated by air pressure through a mechanism inside the gun, while still being initiated manually.

Evaluation

Questions like those listed below can be used for testing, homework assignments and similar evaluation techniques. Observation allows you to visually assess student learning. Assign and review journal entries to evaluate students' learning comprehension through their narratives.

Sample questions:

1. Why did the water from the super soaker travel farther? (Answer: Its design creates greater air pressure behind the flow.)
2. Describe the difference between the water flow generated by a simpler model and a super soaker? (Answer: Due to less pressure, flow is less forceful in a simpler model. A super soaker's flow is sharper and harder. It can sting!)

Observation: Have students either explain or draw how a squirt gun works, using the concepts of pressure, resistance, flow, and distance. Assess and record the level of understanding of these principles demonstrated by their explanations or drawings.

Journal assignment: Write a story about squirt guns. Include data collected during your experiments with squirt guns. (Hint: For younger students, the teacher could record a collective story.)

Extension activity

- Let students repeat the exploration activity using different liquids. Help them discuss whether the type of liquid affects the amount or distance of spray and why.

Subject integration

Geography. Study about dams. For example, have students identify the purposes for dams and the differences in water pressure above and below the dam.

Squirt Gun Testing Data Sheet

Name(s) ____________________

____

Prediction: Which squirt gun do you think will squirt the farthest? Explain.

Directions: Record your observations for each squirt gun test.

Squirt Gun	Distance	Times Pumped
1.		
2.		
3.		
4.		

Conclusions:

FUN WITH PHYSICS:

Real-Life Problem Solving for Grades K-3

Appendices

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APPENDIX A

References

Adkinson, S., M. Fleer, eds. (1995). *Science With Reason*. London: Hodder and Stoughton Educational.

American Association for the Advancement of Science (1993). *Benchmarks for Science Literacy: A Project 2061 Report*. New York: Oxford University Press.

American Association for the Advancement of Science (1990). *Science for All Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology*. New York: Oxford University Press.

Ohio Department of Education (1994). *Ohio's Competency-Based Science Model: Scientific Literacy for the 21st Century*. Columbus, OH: State Board of Education.

National Council of Teachers of Mathematics (1993). *Curriculum and Evaluation Standards for School Mathematics*. Reston, VA: NCTM.

National Research Council (1996). *National Science Educational Standards*. Washington, DC: National Academy Press.

Sadker, M. and D. Sadker (1994). *Failing at Fairness: How America's Schools Cheat Girls*. NY: Charles Scribner's Sons.

The Secretary's Commission on Achieving Necessary Skills (1992). *Learning a Living: A Blueprint for High Performance: A SCANS Report for America 2000*. Washington, DC: U.S. Department of Labor.

APPENDIX B

Resources

Appendix B contains resources for gathering background information about scientific principles that relate to simple machines, electricity, heat, and liquids. In addition, this appendix contains valuable information about learning activities that teachers, parents, and students can use to expand upon the material presented in *Fun with Physics*. Appendix B is divided into the following sections:

- Guidebooks for Educators
- Support Materials for Teachers and Parents
- Hands-On Science Activity Books
- Learning Kits
- Computer Software and Laser Disks
- Suppliers of Science Resources and Materials
- Internet Sites

Guidebooks for Educators

The following guidebooks help educators locate high-quality, age-appropriate science materials.

Association for Supervision and Curriculum Development, Education and Technology Resource Center (1995). *Only the Best: The Annual Guide to the Highest-Rated Educational Software and Multimedia.* Alexandria, VA: ASCD.

The Education and Technology Resource Center compiles an annual list of the highest-rated materials for many subject areas, including science. Judges are leading national software and multimedia evaluators.

National Science Resources Center (1996). *Resources for Teaching Elementary School Science.* Washington, DC: National Academy Press.

This wide range of curriculum materials and references reflect the content and process skills identified in the National Science Education Standards. Reviews of each resource are thorough. Many free or low-cost materials are included.

"Outstanding Science Trade Books for Children for 1995." *Science & Children*, Vol. 32, No. 6 (March 1995).

A panel of educators appointed by the National Science Teachers Association and the Children's Book Council selected this list of 50 science trade books for preschool through 8th grade.

Richter, B. and P. Nelson, eds. (1994). *Every Teacher's Science Booklist.* NY: Scholastic Professional Books.

Scholastic presents short reviews of 890 science book titles published since 1990. It is designed to serve as an aid in selecting quality children's science books, planning classroom activities, and conducting science project research.

Sadker, M. and D. Sadker (1994). *Failing at Fairness: How America's Schools Cheat Girls.* NY: Charles Scribner's Sons.

This book provides a comprehensive report on the results of a national research study into educational equity in the classroom. Concrete, easy-to-implement suggestions for improving equity are also provided and can be used by both educators and parents.

U.S. Department of Energy (1995). *Educators Guide to Free Science Materials*, 36th ed. Randolph, WI: Educators Press Services.

Support Materials for Teachers and Parents

The following comprehensive list of high-quality support materials can help teachers and parents gather information about scientific principles and inquiry-based learning. Many high-quality activities that can be used as extensions to those in *Fun with Physics* are included, as well. Note: Additional resources are listed at the end of each *Fun with Physics* learning activity.

AIMS (Activities Integrating Mathematics and Science)

AIMS is an educational foundation formed to enrich the education of K-9 students through hands-on activities that integrate math, science, technology, and other disciplines. AIMS publishes a newsletter, does teacher training, and publishes many teacher-developed and tested books that are full of practical, easy-to-use learning activities. AIMS can be reached toll free at 888/733-2467. An AIMS catalog can be downloaded from http://www.AIMSedu.org . Selected book titles and their designated grade levels follow:

Mostly Magnets (2-8)
Primary Physics (K-3)
Under Construction (K-2)
Water Precious Water (2-6)
Popping with Power (3-5)
Electrical Connection (4-9)
Soap Films and Bubble (4-9)
Brick Layers: Creative Engineering with LEGO® Constructions (4-9)
Teaching Science with Everyday Things (K-9)

Allison, L. and D. Katz (1983). *Gee Wiz! How to Mix Art and Science or The Art of Thinking Scientifically.* NY: Little, Brown, and Co.

Gee Wiz! is a popular resource for early childhood, hands-on science activities.

Bath, J. (1995). *Science Process Skills: Grades 2-5.* Greensboro, NY: Carson-Dellosa Publishing.

This resource provides teachers with background and learning activities for helping students develop skills in observing, collecting information, communicating, measuring, classifying, inferring, predicting, controlling variables, representing data, hypothesizing, and experimenting.

Bennett, A. and J. Kessler (1996). *Apples, Bubbles, and Crystals: Your Science ABCs.* NY: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

This playful combination of poetry and science activities targets children of ages 4-7.

Bredthauer, V. (1995). *Hands-On Thinking Activities: Centers Through the Year.* Monterey, CA: Evan-Moor Corp.

Bredthauer has designed thoroughly-planned learning centers that focus on scientific and mathematical processing skills such as predicting, estimating, interpreting, sorting, classifying, organizing, and designing. He includes options for independent centers and/or seasonal carnivals, as well.

Carin, A. (1993). *Guided Discovery Activities for Elementary School Science. 3d ed.* NY: Macmillan Publishing Company.

Diehn, G. and T. Krautwurst (1994). *Science Crafts for Kids: 50 Fantastic Things to Invent & Create.* NY: Sterling Publishing Co.

This resource gives teachers and parents a wide variety of activities that combine principles of science and art. Middle- and high school students could use this book independently.

Dunn, S. and R. Larson (1990). *Design Technology: Children's Engineering.* NY: The Falmer Press.

Educational Development Center, Inc. (1994). *Lifting Heavy Things. An Elementary Insights Hands-On Inquiry Science Curriculum.* Newton, MA: EDC.

This curriculum, designed for grades 2-3, provides complete materials and instructional information to help students do inquiry-based learning about pulleys and inclined planes.

Holley, D. (1996). *Science Wise: Discovering Scientific Process Through Problem Solving, Books 1, 2, and 3.* Pacific Grove, CA: Critical Thinking Books & Software, Inc.

Each book is structured around a wide variety of Dynamic Demos and Creative Challenges, which include detailed instructions and discussion questions. Dynamic Demos are teacher-led experiments that carefully guide students through specific steps in order to develop their understanding of scientific process and methodology. (Demonstrations can be modified to become hands-on activities.) Creative Challenges are student-centered tasks that actively engage students' creativity, and critical thinking and problem solving skills. The books were designed for non-science teachers and activities require low-cost materials. Thinking Books & Software can be reached directly at 800/459-4849. These books are also available from the Eisenhower National Clearinghouse and William Sheridan & Associates, which are listed in the Suppliers of Science Resources and Materials section of this appendix.

Gertz, S., D. Portman, and M. Sarquis (1997). *Teaching Physical Science through Children's Literature.* NY: Terrific Science Press/Learning Triangle Press, an imprint of McGraw-Hill, Inc.

The 20 complete lessons in this resource provide a truly integrated approach to teaching hands-on science in the elementary grades.

Jorgensen, M. (1993). *Assessing Habits of the Mind: Performance-based Assessment in Science and Math.* Columbus, OH: ERIC Clearinghouse.

Lawrence Hall of Science, University of California, Berkeley. *Great Explorations in Math and Science (GEMS)*. Berkeley, CA: University of California.

Each GEMS guide comprises a comprehensive, ready-to-use unit on a given topic. Developed for use by non-science teachers, each involves students in hands-on, inquiry-based learning. Science titles are listed below. Other GEMS titles, including those pertaining to biology, ecology, and math, are also available. New titles are developed each year. GEMS materials are available through many suppliers, including William Sheridan Associates, which is listed in the Suppliers of Science Resources and Materials section of this appendix. GEMS staff can be reached directly at 510/642-7771; fax; 510/643-0309. Note: Grade levels are listed after each title; however, most can be adapted for younger or older students.

Bubble Festival (K-6)
Bubble-ology (5-9)
Build It! Festival (K-6)
Frog Math: Predict, Ponder, Play (K-3)
Group Solutions (K-4)
Investigating Artifacts (K-6)
Involving Dissolving (1-3)
Liquid Explorations (1-3)
Mystery Festival (2-9)
Secret Formulas (K-4)
Sifting Through Science: Problem Solving Activities (preschool-2)

Pedagogical handbooks in the GEMS series:

GEMS Teacher's Handbook
GEMS Leader's Handbook
Once Upon a GEMS Guide: Literature Connections
Insights and Outcomes: Assessment for GEMS Activities
A Parent's Guide to GEMS
To Build a House: A Thematic Approach to Teaching Science

Macaulay, D. (1990). *The Way Things Work: From Levers to Lasers, Cars to Computers—A Visual Guide to the World of Machines.* London: Dorling Kinderling Publishers.

Macaulay provides a history of the development of machines. Detailed illustrations show how several everyday machines work. Also available on interactive CD-ROM.

Main, J. and P. Eggen (1991). *Developing Critical Thinking Through Science, Books 1 and 2.* Pacific Grove, CA: Critical Thinking Books and Software, Inc.

Book 1 targets grades 1-4 and Book 2 targets grades 4-6. Both were developed for non-science teachers, involve students in hands-on discovery, and require low-cost materials. Contact Thinking Books & Software directly at 800-459-4849. Also available from William Sheridan & Associates, which is listed in the Suppliers of Science Resources and Materials section of this appendix.

McCormack, A. (1981). *Inventors Workshop.* NY: Fearon Teacher Aids, Simon & Schuster Supplementary Education Group.

This resource provides teachers and/or students with ideas for a wide variety of inventions, including inside-the-box inventions, candle-powered inventions, electrical inventions, and Rube Goldberg contraptions.

Rezba, R., R. Sprague et al. (1995). *Learning and Assessing Science Process Skills, 3rd ed.* Debuque, IA: Kendall/Hunt Publishing.

The wide variety of activities in this book target process skills; each activity is linked to specific competencies.

Sarquis, M. et al. (1995). *Teaching Chemistry with TOYS*. NY: Terrific Science Press/Learning Triangle Press, an imprint of McGraw-Hill, Inc.

A wide variety of practical, well-planned, teacher-tested activities teach process skills and principles of chemistry through discovery and critical thinking. Designed for grades K-9 and adaptable for high school and adult students.

Sherwood, E. et al. (1987; 1992). *Mudpies to Magnets and More Mudpies to Magnets: Science for Young Children*. Mt. Rainier, MD: Gryphon House, Inc.

Each book provides a wide variety of science activities for preschool and early elementary-age students.

Sprung, B. et al. (1990). *Playtime is Science: Implementing a Parent/Child Activity Program*. NY: Educational Equity Concepts, Inc.

Playtime is Science and the companion book (described below) help parents and teachers facilitate hands-on physical science experiences for young children. Step-by-step instructions for planning and running a hands-on science program in a school or child care center are included, and a staff development guide is also available. The activities use everyday materials and science topics include:

- Creating a Mystery Bottle
- Building with "Trashables"
- Solid or Liquid?
- Discovering How it Works
- Making and Using Sieves
- Bubble Science
- In My Estimation

This book is available from WEEA, which is listed in the Suppliers of Science Resources and Materials section of this appendix, or directly from EEC at 212/725-1803; fax 212/725-0947.

Sprung, B., M. Froschl, and P. Campbell (1985). *What Will Happen If..Young Children and the Scientific Method.* NY: Educational Equity Concepts, Inc.

This resource provides teachers and parents with easy-to-understand background about inquiry-based learning and how to use the scientific method with small children. It also includes step-by-step instructions on facilitating learning experiences around topics such as exploring flow with water and sand; exploring momentum with blocks and ramps; exploring solubility, density, and visosity; and understanding how machines work. A staff development guide is also available. The companion book, *Playtime is Science*, is described above. These books are available from WEEA, which is listed in the Suppliers of Science Resources and Materials section of this appendix, or directly from EEC at 212/725-1803; fax 212/725-0947.

Stenmark, J., V. Thompson, and R. Cossey (1986). *Family Math.* Berkeley, CA: Lawrence Hall of Science.

Family Math gives educators, parents, and students a wide variety of activities that target math and problem-solving skills.

Taylor, B. et al. (1995). *Teaching Physics with TOYS.* NY: Terrific Science Press/Learning Triangle Press, an imprint of McGraw-Hill, Inc.

This resource provides a wide variety of practical, well-planned, teacher-tested activities for teaching process skills and principles of physics through discovery and critical thinking. Designed for grades K-9 and adaptable for high school and adult students.

Taylor, B. (1997). *Teaching Energy with TOYS.* NY: Terrific Science Press/Learning Triangle Press, an imprint of McGraw-Hill, Inc.

This book supplies a wide variety of practical, well-planned, teacher-tested activities to teach process skills and principles of energy through discovery and critical thinking. Designed for grades K-9.

Hands-On Science Activity Books

These resources contain learning activities that students can complete independently or with instructional support. They also provide teachers and parents with great ideas for facilitating science-related activities. In addition, information about basic scientific principles can be found in many of these books. Note: Additional, topic-specific books are listed at the end of each *Fun With Physics* learning activity.

American Chemical Society. *Wonder Science: Fun Physical Science Activities for Children and Adults to Do Together.*

Since 1989, children and adults have been reading about science and doing the well-planned activities described in the Wonder Science newsletter. For under $10 per year, children receive 8 newsletters on topics such as insulation, playground physics, inventions, heat/convection, plastics, forces, aerodynamics, and food chemistry.

Ardley, Neil (1991). The Science Book Series includes the following books, which are published by Harcourt, Brace, and Javonovich.

The Science Book of Air
The Science Book of Color
The Science Book of Water

Ardley, Neil (1993). *101 Great Science Experiments: a Step-by-Step Guide.* London: Dorling Kindersley Limited.

This guide provides background information and activities that demonstrate physical science principles about topics such as air and gases, water and liquids, hot and cold, color, magnets, electricity, and motion and machines.

Ardley, Neil et al. (1984). *How Things Work.* NY: Simon and Schuster, Inc.

This book provides simple explanations about how things work, including flashlights, magnets, car batteries, electric motors, transformers, electromagnets, fire extinguishers.

Barber, N. And T. Keegan (1990). *175 More Science Experiments.* NY: Random House.

Brown, Sam, ed. (1981). *Bubbles, Rainbows, and Worms: Science Experiments for Pre-School Children.* Mt. Rainier, MD: Gryphon House, Inc.

Caney, S. (1980). *Steven Caney's Invention Book.* NY: Workman Publishing.

Caney offers many examples of inventions that have been and/or can be created. Also available on CD-ROM.

Carow, R. (1996). *Put a Fan in Your Hat!: Inventions, Contraptions, and Gadgets Kids Can Build.* NY: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

Gardner, R. (1990). *Investigate and Discover Forces and Machines.* NY: Franklin Institute Science Museum.

Gateway's Simple Machines Series includes the following titles:

Inclined Planes

Levers

Pulleys

Hann, J. (1991). *How Science Works.* Pleasantville, NY: Reader's Digest.

Helpful for students, teachers, and parents, this well-illustrated book of activities and information is organized around basic science topics.

Iovine, J. (1991). *Homemade Holograms: The Complete Guide to Inexpensive, Do-it-Yourself Holography.* NY: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

Kerrod, R. (1990). *How Things Work.* NY: Marshall Cavendish Publishing.

The functioning of common machines (e.g., clocks, automated teller machines, satellites) is explained. Kerrod includes an illustrated glossary and a section that outlines the scientific principles at work in many machines.

Kohl, M. A. and J. Potter (1993). *Science Arts: Discovering Science Through Art Experiences.* Bellingham, WA: Bright Ring Publishing.

This resource helps students from age 3-14 experience many scientific principles related to air and water, light and sound, motion and energy, and reaction and matter.

Laux, K. (1997). *The World's Greatest Paper Airplane and Toy Book.* NY: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

Levenson, E. (1994). *Teaching Children about Physical Science: Ideas and Activities Every Teacher and Parent Can Use.* NY: McGraw-Hill, Inc.

This resource not only provides information about basic physical science principles, but also suggests a wide variety of activities that demonstrate those principles.

Sobey, E. (1996). *Wrapper Rockets and Trombone Straws: Science at Every Meal.* NY: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

Taylor, B. *Steps into Science Series.* NY: Random House. Titles include:

Get It In Gear: The Science of Movement
Over the Rainbow: The Science of Color and Light
Up, Up & Away!: The Science of Flight

VanCleave, J., author of many science books published by John Wiley & Sons, Inc., including:

Chemistry for Every Kid: 101 Easy Experiments that Really Work
Gravity: Mind-boggling Experiments You Can Turn into Science Fair Projects
Machines: Mind-boggling Experiments You Can Turn into Science Fair Projects
Magnets: Mind-boggling Experiments You Can Turn into Science Fair Projects
Physics for Every Kid: 101 Easy Experiments in Motion, Heat, Light, Machines, and Sound
200 Gooey, Slippery, Slimy, Weird & Fun Experiments
200 More Gooey, Slippery, Slimy, Weird & Fun Experiments

Walpole, B. (1988). *175 Science Experiments.* NY: Random House.

Willow, D. and E. Curran (1989). *Science Sensations: Easy-to-do Activities that Explore the Science Behind Such Everyday Marvels as Rainbows, Bubbles, and Kaleidoscopes.* Boston, MA: Addison-Wesley Publishing Company.

Wood, R. (1996). *Mechanics FUNdamentals: FUNtastic Science Activities for Kids.* NY: Terrific Science Press/Learning Triangle Press, an imprint of McGraw-Hill.

Wellnitz, W. (1993). *Homemade Slime and Rubber Bones!: Awesome Science Activities.* NY: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

Wellnitz, W. (1993). *Be a Kid Physicist.* NY: Learning Triangle Press, an imprint of McGraw-Hill, Inc.

Zubrowski, B. *Boston Children's Museum Activity Book Series.* Beech Tree Paperback Books, Inc.

Zubrowski has written many science books for this series. Titles include:

- *Bubbles*
- *Balloons: Building and Experimenting with Inflatable Toys*
- *Blinkers and Buzzers: Building and Experimenting with Electricity and Magnetism*
- *Inks, Food Colors, and Papers*
- *Messing Around with Baking Chemistry*
- *Messing Around with Drinking Straw Construction*
- *Raceways: Having Fun with Balls and Tracks*
- *200 Gooey, Slippery, Slimy, Weird & Fun Experiments*
- *Tops: Building and Experimenting with Spinning Toys*
- *Wheels at Work: Building and Experimenting with Models of Machines*

Learning Kits

These kits contain all of the information, and some or all of the materials, needed to teach a unit. Suppliers such as Delta Educational sell additional kits on a wide variety of topics and William Sheridan & Associates develops custom-made kits upon request. Information about these retailers is provided in the Suppliers of Science Resources and Materials section of this appendix.

Scholastic Science Place, Sampler Edition (1995). NY: Scholastic, Inc.

The Science Place series was developed through a collaboration between Scholastic and the nation's leading science museums. It is a hands-on, thematic, core K-6 program comprising six complete kits for each grade. Each kit includes books, teacher's map to exploration, reusable exploration materials, sciencemats, assessment collection, recording board, home connection collection, videotape, and a bag. All units can be adapted for younger or older students. These kits can be purchased from Scholastic at 800/724-6527; fax 314/653-5881; http://www.scholastic.com. Also available from The Eisenhower National Clearinghouse, which is listed in the Suppliers of Science Resources and Materials section of this appendix.

How Buildings Work: How People Use Materials to Build Structures (grade 3)

How People Use Electricity: How Electric Energy Works (grade 4)

Motion: How Moving Objects Interact (grade 4)

How People Invent: How Problems and Solutions Change Over Time (grade 5)

Computer Software and Laser Disks

Many of the software programs on the market are not much more than a workbook of drills designed to reinforce basic skills. Educators and parents are encouraged to select software that targets students' *critical thinking and problem-solving* skills. The following software titles meet this criteria.

Gryphon Bricks

This interactive software, sold through Gryphon Publishing, provides users, age 6 and up, with more than 200 styles of bricks to build whatever their imaginations can dream up.

The Incredible Machine

This interactive CD-ROM, developed and distributed by Sierra Software, allows students ages 9 and up to analyze how machines work and create their own machines and contraptions.

The Learning Company, Inc. provides several titles that help students build basic mathematical or science principles. In addition, students are given many opportunities to practice hands-on experimentation, deductive reasoning, and real-world problem solving. The following programs are available from The Learning Company, One Anthenaeum Street, Cambridge, MA 02142; 800/227-5609.

Treasure Math Storm! (ages 6-8)
Treasure Galaxy! (ages 6-8)
Super Solvers OutNumbered! (ages 8-10)
Super Solvers Gizmos & Gadgets! (ages 8-10)

Sammy's Science House

Students from preschool to grade 2 can practice the fundamentals of observing, predicting, constructing, classifying, comparing, and sequencing in 5 fun activities. The program was field tested and given very high ratings by teachers participating in the Ohio SchoolNet Plus Software Review Project. Distributed by Edmark Corporation, P.O. Box 97012, Redmond, WA 98073; 800/362-2890; fax 206/556-8430; edmarkteam@edmark.com. Also available from The Eisenhower National Clearinghouse, which is listed in the Suppliers of Science Resources and Materials section of this appendix.

Science Sleuths

Science Sleuths invites students to solve science mysteries that introduce them to problem solving, critical thinking, the scientific method, and specific scientific concepts and terms. An automated student notebook and teacher assessment are included. Science Sleuths was developed for grades 3-6. However, each interactive mystery has 6 progressively more challenging levels to play, each with a different solution, so they can be customized to virtually any grade level. This series is available on CD-ROM (volumes I and II, with 4 mysteries) and video disk (with 24 mysteries). Teachers guides are available. Developed in collaboration with Scholastic, Inc., the materials are sold through Videodiscovery, Inc., 1700 Westlake Avenue North, Suite 6000, Seattle, WA 98109-3012; 800/548-3472; fax 206/285-9245; http://www.videodiscovery.com/vdyweb. Also available from The Eisenhower National Clearinghouse, which is listed in the Suppliers of Science Resources and Materials section of this appendix.

The Way Things Work: A Unique Guide to A Magical World of Machines, Inventions, and Technology

This software mirrors the book of the same title, which was designed by David Mcaulay and Dorling Kindersley Publishing for students in grades 5 and up. Use this interactive CD-ROM to learn about inventors, inventions, scientific principles, and history. Topics range from light bulbs to lasers.

Widget Workshop: The Mad Scientist's Laboratory

This software package, designed for grades 4 and above, is a science construction kit that enables students to design and build mechanical inventions (e.g., puzzles, machines) using simulated parts. The package is distributed by Maris Multimedia, Ltd., 2 Theatre Square, Suite 2302, Orinda, CA 94563-3346; 800/336-2947; fax 510/253-3736. Also available from The Eisenhower National Clearinghouse, which is listed in the Suppliers of Science Resources and Materials section of this appendix.

Suppliers of Science Resources and Materials

Burt Harrison & Company

Burt Harrison is a favorite supplier of "batteries and bulbs activities" among *Fun with Physics* contributors. In addition to basic electricity-related supplies, the company sells activity cards, motor kits, and similar materials developed by Burt Harrison. Contact the company at P.O. Box 732, Weston, MA 02193; 617/647-0674

Delta Education

Delta provides a wide variety of science materials that can be used in hands-on science activities. In addition, they carry many kits on topics such as electricity, bubble science, color and light, electromagnetism, lenses and mirrors, and simple machines. Contact Delta at P.O. Box 3000, Nashua, NH 03061; 800/442-5444.

Eisenhower National Clearinghouse for Mathematics and Science Education (ENC)

The ENC was established to help K-12 teachers locate useful teaching materials. The clearinghouse collects all types of materials at its repository in Columbus at The Ohio State University. (It is not a lending library.) The ENC reference desk is located at 1929 Kenny Road, Columbus, Ohio 43210-1079; 800/621-5785; 614/292-7784; fax 614/292-2066; e-mail info@enc.org. Free materials are available from their web site, http://www.enc.org.

Great Explorations in Math and Science (GEMS)

GEMS develops materials and provides in-service training to educators on topics related to inquiry-based science and math. Much of their work is done through regional support centers/ network sites. The GEMS materials, which are listed in Appendix B, can be obtained from William Sheridan and Associates (listed in this section) or directly from GEMS. GEMS staff can be reached at Lawrence Hall of Science, University of California, Berkeley, CA 94720-5200; 510/642-7771; fax 510/643-0309.

National Science Foundation (NSF)

NSF provides a toll-free service that answers questions about science. NSF also distributes learning materials and awards grants to educators. The foundation can be reached at 800/682-2716 or through its home page at http://www.nsf.gov/od/lpa/nstw/quests/start.htm.

Women's Educational Equity Act (WEEA) Program Publishing Center

WEEA distributes a wide variety of materials on topics related to educational equity, including disabilities, gender equity, careers, history, math, science, and technology. Materials and catalogs are available from WEEA at 55 Chapel Street, Suite 224, Newton, MA 02158-1060; 800/793-5076; e-mail WEEApub@EDC.org. Their web site can be found at http://www.edc.org/CEEC/WEEA.

William Sheridan & Associates

Sheridan & Associates provides a wide variety of science, math, and language arts materials. The company carries an amazing inventory of written resources as well—including most of those listed on the previous pages. They also create custom-designed learning kits on a wide variety of science topics. Bill Sheridan and his staff have a reputation for friendly, personal service and locating almost anything a customer needs. They have several catalogs of their own, and supply the materials found in the Basic Science, Flinn Scientific, Connecticut Valley Biological catalogs, too. Their Discovery Store is open to the public, and located at 8311 Green Meadows Drive N., Lewis Center, Ohio 43035 (just north of Columbus). Call them at 800/433-6259; fax 614/548-0485.

Internet Sites*

Resource	Internet Address
Bill Nye, The Science Guy	http://www.nyelabs.kcts.org/
Clearinghouse for Mathematics and Science Education	http://www.nsta.org
Eisenhower National Clearinghouse	http://www.enc.org
The Exploratorium Science Snackbook	http://www.exploratorium.edu/publications/Snackbook/Snackbook.html
Implementing Science Education Standards	http://cedar/cic/net/ncrel/sdrs/areas/issues/content/cntareas/science/sc300.htm
Improving Math & Science Education	http://www.learner.org/content/k12
Issues in Science and Technology	http://www.utdallas.edu/research/issues/
Lawrence Hall of Science	http://www.lhs.berkeley.edu/
McGraw-Hill Publishers	http://www.mcgraw-hill.com
NASA	http://quest.arc.nasa.gov/women/teachingtips.html
National Science Foundation	http://www.nsf.gov
National Science Education Standards	http://www.nap.edu/readingroom/
National Science Teachers Association	http://www.nsta.org
Newton's Apple Educational Materials	http://ericir.syr.edu/Newton/welcome.html
NPR Science Friday Kids Connection	http://www.npr.org/sfkids/index.html
The Science Club	http://www.halcyon.com/sciclub/
Science Education Resources	http://www.edu/intec/science.html
Science, Technology, and Society Links	http://gpu2.srv.ualberta.ca/_slis/guides/scitech/kmc.htm/
U.S. Department of Energy	http://www.doe.gov

*Internet addresses were correct upon Fun with Physics publication. They are subject to change.

APPENDIX C

Basic Scientific Principles

Fun with Physics focuses on simple machines, electricity, heat, and liquids. Appendix C provides scientific background knowledge relative to these topics. It may be especially helpful for non-science teachers. The background information is organized for quick reference, as follows:

- Scientific Principles and Laws
- Generalizations About *Simple Machines*
- Overview of *Electricity*
- Generalizations About *Electricity*
- Generalizations About *Heat*
- Generalizations About *Liquids*

Scientific Principles and Laws

Bernoulli's principle: The faster the flow of air or fluid, the lower the pressure.

Boyle's law: Pressure is affected by the force exerted on a unit of the surface—the smaller the surface, the greater the pressure (given the same force and a constant temperature).

Charles' law: If a gas's temperature is raised, its volume also increases by the same ratio (providing its pressure remains constant). Or, if a gas's temperature is raised, its pressure increases by the same ratio (providing its volume remains constant).

Hooke's law: The greater the force exerted on an object, the more it will be moved. In other words, the force applied to a spring is directly proportionate to the distance the spring is stretched. So, the heavier the weight pulling on a spring, the farther the spring stretches.

Newton's laws of motion:

- An object will remain at rest or in uniform motion unless acted upon by an outside force.
- When a force acts upon an object, it changes the momentum of that object, and this change is proportionate to the applied force and to the time that it acts upon the object.
- Every action (i.e., force) is followed by an equal and opposite reaction (i.e., force).

Laws of thermodynamic: Heat energy always flows spontaneously from hot to cold.

Law of conservation of energy: Energy cannot be created or destroyed.

Ohm's law: Current is directly proportionate to the voltage and inversely proportionate to the resistance.

Pascal's law: Pressure added to a confined fluid at any point instantly appears equally at all other points, and is always at right angles to the containing surfaces.

Generalizations About *Simple Machines*

A **machine** is something that performs work.

Work is done when a force causes an object to move.

Simple machines, which are described below, make up compound (or complex) machines.

Examples of **compound machines** include a bicycle, a rod and reel, a typewriter, a can opener, a scissors, a hand drill, a car, a weight machine, and a treadmill.

Gears

- The force that is applied to a driver gear is transferred to a driven gear.
- When two gears of different sizes are meshed together, the smaller gear turns faster (more rotations per minute) than the larger gear.
- Gears that are side-by-side and meshed together move in opposite directions.
- The direction and speed of the driver gear determines the speed and direction of gears that are meshed with it.

Pulleys

- A pulley is a wheel with a rope, belt, or chain around it.
- Pulleys change the direction of movement and make work easier.
- Fixed pulleys change the direction that an object is moved; they do not make work easier.
- Moveable pulleys change the direction that something is moved and make work easier.
- The more pulleys in the system, the easier it is to do work (e.g., pulling or lifting an object).

- The more pulleys involved in a system, the greater distance to be pulled, but the easier it is to do work.
- The thinner the windlass, the easier it is to turn.
- Two different sets of pulleys will turn at the same speed, if the wheels are connected by a shaft and both pairs of pulley wheels are the same size.
- Common pulleys include crankshafts, sailboats, and window blinds.

Inclined planes

- An inclined plane is a slanted surface that is used to raise or lower heavy objects from one position to another.
- Inclined planes help reduce the amount of force needed to complete a given amount of work, but require greater distance.
- The steeper the plane, the more difficult the work.
- Wedges are two back-to-back inclined planes.
- Common inclined planes are a screw, a bolt, a drill bit, a clamp, a car jack, and a bottle top.

Levers

- A lever is a bar or rod that is free to move or turn on a fulcrum.
- A lever multiplies force, but some distance must be given up.
- The shorter the effort arm, the less force is attained and the greater distance is attained.
- The longer the effort arm, the more force is attained and the less distance is attained.
- Examples of levers include scissors, a broom, a claw hammer, a nutcracker, a mop, tongs, a crowbar, a can opener, tweezers, a baseball bat, boat oars, and a car jack handle.

Wheel and axle

- A wheel and axle is like a spinning lever (e.g., an ice cream machine crank).
- The center of the axle is the fulcrum.
- The wheel is larger than the axle; the wheel turns a greater distance than the axle turns. Work is done at the wheel and is multiplied at the axle.
- Common wheel and axle combinations include a screwdriver, roller skates, a water faucet handle, a bicycle pedal, a can opener, a car steering wheel, and a clock.

Overview of Electricity

Electricity is the continuous flow of electrons, or **current**, from one atom to another. No electron flow will occur unless there is a pathway over which the electrons can move. This flow is similar to a water system, where pipes or hoses move water from storage tanks to the delivery point. In electrical wiring, the pathway through which electrical current flows is called a circuit. A simple **circuit** consists of a power source, conductors, load, and a device for controlling current. Each is described below.

- In buildings, the **power source** could be considered the electrical generating stations that pump electricity into residential and commercial buildings. However, primary sources of electrical power also include small generators and batteries.
- **Conductors**, or wiring, provide a path for the current so that it can travel from one point to another.
- A **load** is a device through which electricity produces work. For example, a lamp is a load that, when plugged in and turned on, produces light. Other examples of loads include heaters, electric motors, and televisions.
- **Switches** (e.g., on-off switches) control when the electrical current flows through circuits.
- **Fuses** and **circuit breakers** are protective devices that control current by preventing too much current from flowing into the circuit, which would damage equipment. When an excessive amount of electricity passes through them, fuses and circuit breakers "blow" (shut down) to stop the flow of electricity through the circuit.

In a circuit, **resistance** lowers the amount of electrical energy available to do work. Both wires and load affect resistance. It might be helpful to think of a similar situation with a hose that is connected to two sprinklers. As water passes through a hose, turns or kinks in the pathway cause friction (which is resistance) that results in a slower flow. In addition, when some of the water is diverted to the first sprinkler (which is a load), less water is available for use in the second sprinkler.

There are two types of *current flow*. Current is either **direct** (flowing in one direction) or **alternating** (flowing in one direction, then reversing to the other direction approximately 60 times per second). In most cases, direct current is provided to equipment by batteries (e.g., flashlights, portable radios, and cars). Alternating current is provided to equipment through electrical systems in buildings.

Measurement of electric current

The *rate* at which electricity flows is called **amperage**. It is measured in **amperes**. A 100-watt bulb requires a current of approximately 1 ampere to make it light up completely. Current flow is measured with an **ammeter**. Most heating and power equipment indicates the amount of current needed for proper operation.

Measurement of electrical pressure

Pressure is applied to electrons to force them to move through a conductor and around a circuit. This pressure is measured in **volts**. The pressure, or **voltage**, is available in wiring circuits all of the time—whether or not electrical equipment is being used. Voltage is measured with a **voltmeter**.

Calculation of power

The amount of *power* derived from an electrical device or system is called **wattage**. Wattage is the product obtained from electrical energy; it is the power that we put to use for lights, heating, cooking, hot water and other everyday needs. For example, the electric company sells electrical energy. Electrical energy or power is measured in **watts** and can be calculated as follows:

For direct-current circuits: volts x amperes = watts

For alternating-current circuits: volts x amperes x power factor = watts

NOTE: Power factors range from 0-1. Large equipment (e.g., an electric heater) may have a power factor as high as 1; small equipment (e.g., a small engine) may have a power factor as low as .25.

Ohm's law

Ohm's law is a simple formula used to describe the relationship between *current* (flow), *voltage* (pressure), and *resistance* of an electrical circuit. Each component interacts to affect the operation of a circuit. In other words, because voltage pushes current through a resistance, a change in any of these components will result in a change in the others. The following three equations are Ohm's law rearranged to solve for each of the quantities:

Current = Voltage ÷ Resistance	$I = E/R$
amps = volts ÷ ohms	An increase in voltage causes an increase in electrical current flow. An increase in circuit resistance causes a decrease in electrical current flow.

Voltage = Current x Resistance	$E = I \times R$
volts = amps x ohms	An increase in current causes an increase in voltage. An increase in resistance causes an increase in voltage.
Resistance = Voltage ÷ Current	$R = E/I$
ohms = volts ÷ amps	An increase in voltage causes an increase in resistance. An increase in current causes a decrease in resistance.

Generalizations About Electricity

- The longer the wire, the greater the resistance; the thinner the wire, the greater the resistance.
- An increase in the temperature of a wire causes an increase in resistance.
- An ordinary electrical cord has two wires; one for the flow of current from the power source and the other for the return or ground.
- The voltage (pressure) and current (flow of electricity) directly affect how much power is available to do work. Less energy source or lower flow will result in less electrical power being produced and vice versa.
- A series circuit has only one path for the flow of current. In a series circuit, objects are placed one after another and the current flows through each of them in succession. The current is the same throughout, however, and the voltage is divided among the objects in the circuit.
- In a parallel circuit, there are 2 or more paths, or branches, for the flow of current. The current will divide and flow through each of the paths simultaneously. Every branch has the same voltage and—if the appliances are all the same—will have the same amount of current. The total circuit resistance is less than any one branch.
- When batteries are connected in a series, the current is the same; the total voltage is the sum of the voltage of each battery. The terminals are connected +, –, +, –, and so on.
- When batteries are connected in parallel, the total current is the sum of the currents in each battery; the total voltage is the same as that of one cell. The terminals are connected +, +, +, and –, –, –.

Generalizations About Heat

- Heat travels through conductors (e.g., metal) better than through insulators (e.g., wood).
- Dark-colored surfaces absorb more heat than light-colored surfaces.
- Rough or dull surfaces absorb more heat than smooth or shiny surfaces.
- When friction causes heat, the object that is in constant contact gets hotter than the movable object (e.g., the wood being cut gets hotter than the saw blade, car brake shoes get hotter than the wheel).

Generalizations About Liquids

Pressure

- The amount of pressure exerted by a fluid depends upon the height and the density of that fluid and is independent of the shape of the container that is holding the fluid.
- The deeper the fluid, the greater the pressure it exerts.
- The denser the fluid, the greater the pressure it exerts (e.g., salt water is denser than fresh water).
- Fluids seek equilibrium—seek their own level; a fluid will flow from a place of high pressure to a place of low pressure.
- A fluid can never rise higher than its source without an external force (e.g., a pump).

Evaporation

- The higher a liquid's temperature, the faster it will evaporate.
- The lower a liquid's pressure, the faster the liquid will evaporate.
- The more surface area of a liquid that is exposed to air, the faster the liquid will evaporate.
- The more circulation of air above a liquid, the faster the liquid will evaporate.

Boiling point

- Increased pressure on a liquid raises the liquid's boiling point.
- Decreased pressure on a liquid lowers the liquid's boiling point.

Buoyancy

- The easier an object floats, the denser the liquid or the lighter the object's weight.

APPENDIX D

Gender Equity: What Can I Do?

Teachers face an important challenge: to provide learning opportunities that will help **all** students succeed. **Gender equity** is an aspect of instruction that teachers need to consider in order to meet this challenge, *especially* when planning to help students develop science and related skills. Unfortunately, gender equity is often overlooked in math, science, and technology instruction.

Many girls do not have the same types of **experiences**, either inside or outside of school, as boys. As a result, boys and girls have traditionally received **differing qualities of education**—even when they study in the same classroom. You may be skeptical about this—especially if you are male. Please don't stop reading; review this simple list and check it out for yourself. Researchers[1] have found the following inequities in the way that boys and girls are treated in school:

- From preschool to graduate school, **female students receive less teacher attention** and **less useful teacher feedback**.
    - ✔ Teachers **call on** girls less often than they call on boys.
    - ✔ Teachers ask fewer **probing and higher-order thinking questions** of girls than they do of boys.
    - ✔ Teachers often **give** boys **instructions** for performing tasks, but tend to *do* the same tasks *for* girls.
    - ✔ Teachers tend to give girls less **feedback** (e.g., praise, criticism) than they give boys.

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[1] The most comprehensive research on the topic of gender equity has been done by Myra and David Sadker. Their findings are published in Failing at Fairness: How America's Schools Cheat Girls (1994).

- In class, **girls talk significantly less** than boys do.
    - ✓ In elementary and secondary school, girls are eight times less likely to **call out** comments. When they do, they are often reminded to raise their hands, while similar behavior by boys is accepted.
    - ✓ Girls are less likely to **raise their hands**. Reasons for this are that they are aware that boys get called on more, they may take longer than boys to think about their responses before raising their hands, and they may not have confidence in their ability to answer correctly.
- When working in **mixed gender pairs**, boys tend to dominate in math, science, and technology-related activities. Such dominance results in girls having fewer opportunities to do hands-on learning in these subject areas.
- **Females' contributions** are rarely mentioned in the curriculum. Most textbooks continue to report male contributions and include pictures of boys actively doing things while girls passively watch and support them.
- Girls experience **pressure** from their friends to *not* do well in science, math, and technology-related classes; they may be teased for being "nerdy" or not feminine if they try to do well.
- Outside the classroom, most girls have not been given **opportunities to work with tools or mechanical systems.** And they aren't given as many toys that encourage them to build, explore, or tinker. For example, girls do not generally build with LEGOs® or fix their own bicycles. And similar to classroom situations, adults tend to give instructions to boys on how to perform tasks, but tend to do tasks for girls. As a result, many female students have not developed the foundational skills necessary to succeed in science, math and technology classes.

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This **subconscious** inequity has far-reaching **consequences**. Because girls have had fewer opportunities to develop "mechanical" skills, they are often less prepared for and less likely to take courses in math, science, and technology. In addition, it is clear from the research that those girls who do take upper-level math and science courses are also treated very differently than their male classmates; therefore, many stop taking such courses. Taking fewer of these courses has resulted in fewer high-paying occupational options for female workers.

What can teachers and parents do to help girls and boys have equal chances to successfully develop math, science and technology skills? The following list provides some ideas:

1. The most important thing that you can do, as a male or female teacher, is to **be aware of your subconscious bias** and to accept that virtually everyone has been socialized to have that bias. (If you don't believe that you treat boys and girls differently, ask a colleague to observe you in the class room or make a videotape of your teaching or training to determine whether you provide girls with less attention and different expectations than you do boys.)
2. Make a conscious effort to **provide boys and girls with equal amounts of attention**. Some teachers alternate calling on boys and girls. Others monitor which students they call on with a written record.

3. **Create an atmosphere that fosters girls' participation.** Because girls are generally shyer than boys about speaking in public, you must encourage them to express themselves by making small changes in your own behavior. For example, when asking questions in mixed gender settings, make a conscious effort to **wait** 5-10 seconds before calling on anyone. You'll be surprised at the number of timid hands that go up in those few seconds. Or, if only ⅓ of the students have their hands up after you ask a question, you might want to say, "Think about it and talk with the person sitting next to you. I'll ask again in a few minutes."
4. **Encourage girls to participate in activities they might not normally try** (e.g, using tools, taking leadership roles).
5. **Pay attention to group dynamics**—who speaks, how often, for how long, in what order, and who interrupts whom. Since girls tend to speak less often and for shorter periods of time, be sure to acknowledge their contributions. Teachers can take this into account when grouping students for learning activities. Sometimes, it is helpful to assign same-gender teams.
6. **Don't "teach down" to any students.** Expect equally **high** performances from boys and girls and of people of all races and national origins (e.g., don't assume that a female student can't use tools or analyze complicated systems).
7. When setting up the classroom, **arrange seating for gender-balance.**

8. **Involve female students in construction and manipulation of equipment and use of tools.** They may not have experience in these areas, e.g., many girls have not used pliers, pipe wrenches, handsaws, electric drills, ratchet sets, ohmmeters, micrometers, gauges, or bench vises. They simply have not been given opportunities to gain this experience. Therefore, teachers should make a special effort to provide opportunities for them to learn these skills.
9. **Provide female students with additional instruction or practice, when needed.**
10. **Use a collaborative, cooperative approach to activities** rather than a competitive one.
11. **Use interactive methods.** Have students do some of their work in small groups. Girls tend to be more effective when they can share their ideas with others. And it helps boys develop these skills.
12. To prevent boys from dominating activities in which they have higher skills due to more experience, **pair girls with girls and boys with boys** some of the time.
13. **Foster girls' independence**. Hold them accountable when they engage in "learned helpless" behavior. When they say "I can't do it" before exerting effort, find ways to re-engage them in the activity. Show faith in their abilities to do things for themselves.
14. Ask both girls and boys to **help with heavy equipment and books.** Encourage students (both male and female) of smaller stature to simply carry fewer books or seek more help. Help them learn to take responsibility for accommodating their own physical size needs rather than avoid physical activities.

15. Use **more than one method of assessing students' achievement**. For instance, evaluate through multiple-choice tests and model building (at which boys tend to perform better), as well as essay tests, projects, and reports (at which girls tend to perform better). Refer to the Assessment section, pp. 45-51, for additional options. In addition, assessment strategies are suggested for each *Fun with Physics* learning activity.

APPENDIX E

Design Projects that Promote the Integration of Problem-Solving, Process Skills, and Scientific Principles

It is strongly recommended that teachers try each of these activities themselves before assigning them to students.

Introduction

If students are to function successfully in today's world, they must learn how to apply their varied academic knowledge and experiences to practical, real-life situations. It is never too early to teach students to solve problems—in preparation for those they will encounter at home, in their communities, and eventually, at work. **Design projects** can help students of all ages integrate the development of problem-solving skills, process skills, and scientific principles through hands-on applications. Thus, teachers who provide students with frequent and ongoing opportunities to practice these skills is helping students prepare for later life.

Design Projects Help Students Practice Problem Solving and Process Skills

Design projects (i.e., learning activities that require students to design a product) offer some of the best problem-solving practice—especially for integrating learning around the sciences. Design activities not only help students investigate principles of physics, but they also let them practice math, communication, and multiple process skills. (See information concerning the importance of process skills, pp. 25-32). In other words, design activities help students practice many of the skills involved in the scientific process, e.g., they develop plans, implement them, and evaluate the effectiveness of their designs.

The activities in this appendix can help teachers meet the challenge of preparing students to solve real-world problems; it contains several design projects that can be used with students of most ages. Other resources listed in the Resource section (Appendix B, pp. 293-314) can provide additional design project ideas. In addition, several of the learning activities in *Fun with Physics* involve students in designing something.

Design Activities **Page**

Sturdy Rafts 337

Build the Highest Tower 341

Flying Machine 344

Inventions 346

Black Boxes 350

STURDY RAFTS

Learning objective

Students will engineer a raft to carry the greatest load of pennies as it sails across a sink or tub of water.

Materials

Regular-size drinking straws

Masking tape

Modeling clay

Pennies (if unavailable, other items can be used, e.g., counting bears)

Sink or plastic tub

Sturdy Rafts data sheet

Hint: You may wish to let students select their own materials from a wide range of options in order to provide them more design options and enhanced experimentation. However, if you feel it is important to limit the materials, use those listed.

Exploration activity

1. Students can work individually or in pairs.
2. Have students draw a design of the raft they plan to build. Instruct them to use pencils so that changes can be made easily.
3. Provide ample time for students to build their rafts.
4. Have students test their raft designs by placing pennies on their rafts and sailing them across a sink or a tub of water.
5. Instruct students to record their findings on the Sturdy Rafts data sheet.
6. Encourage students to improve their designs, e.g., so the rafts can carry more pennies.

7. Have students test their modified rafts and record their findings. *(Hint: Making modifications is critical to students' success with the scientific process. Be sure to allow plenty of time for this step and to encourage and guide students, as needed.)*
8. Conduct a group discussion concerning the test results. Be sure to facilitate in a way that helps students recognize the scientific process at work in their experiments.

Explanation

Engineers are responsible for designing most types of crafts, from 6-foot rowboats to the largest aircraft carriers. Even though engineers have designed a variety of high-tech boats, many people still enjoy one of the most basic watercrafts—the raft. Challenge your students by having them design their own rafts.

Extension activities

See the References listed on pp. 293-314 for related learning activities.

Sturdy Rafts Data Sheet

Name(s) ______________________________

Number of Pennies on the Raft	What We Observed
Trial 1	
Trial 2	
Trial 3	

Conclusions:

BUILD THE HIGHEST TOWER

Learning objective

Students will use nontraditional materials to build the highest tower they can.

Materials (per student)

2 pieces of paper

10 paper clips

Scissors

Hint: You will also need a yardstick or measuring tape to measure tower heights. Alternately, you can place a strip of masking tape vertically on a wall or doorjamb starting at the floor and extending about 5 feet; the names or initials of each student/student pair can be written at the respective tower heights.

Note: Students can work individually, in pairs, or in small teams.

Exploration activity

1. Give students the following instructions (and no other information):
   - Build a tower.
   - Only the materials provided may be used to build the tower.
   - The tower must be free standing. It cannot lean against a wall or be held up.
   - Towers must be brought to the tape on the wall for measuring (optional).
2. Measure the height of each structure as it is completed. If you are using the masking tape measuring site, have students bring their towers to the wall and write their initials/names at the respective tower heights.

3. When all towers have been measured, announce the winners.
4. Have students examine all of the towers.
5. Facilitate a discussion about the design strategies that made some towers more successful than others. Be sure to relate building towers to building houses and office structures.

Explanation

Help students recognize that their activities generally mirrored those of architects and engineers. Increase their awareness of how they used the scientific process in their experiments.

Extension activities

- Let students repeat the exploration activity, but instruct them to take 15 minutes to experiment with scratch paper before they actually begin their second construction.
- Allow students to complete the exploration exercise with different materials:
  - Use miniature marshmallows, spice drops, modeling clay, and/or dried peas that have been soaked in water as connectors.
  - Provide uncooked spaghetti, toothpicks, plastic rods, and/or straws for building materials.
- Instruct students that their goal is to build a structure as high as they can with some or all of the materials.
- Have students work in pairs to design a bridge that will span the distance between the arms of a chair so that the center of the span will support a roll of toilet paper. Their goal is to do this with the fewest possible materials. Materials might include tongue depressors, pipe cleaners, plastic rods, paper clips, and/or straws.

- Using no more than 25 building pieces (e.g., LEGOs®) have students construct the tallest possible freestanding structure.
- Using only newspaper (no other materials or equipment), have students construct the longest possible freestanding bridge.

FLYING MACHINE

Learning objective

Students will practice solving problems through flight experiments.

Materials

Paper of different types and weights (e.g., notebook paper, copier paper, 80-pound paper, card stock, construction paper)

Paper clips

Exploration activity

1. Challenge students to make a single sheet of notebook paper travel as far as possible.
2. Once paper airplanes are designed, give students plenty of time to experiment by flying their airplanes (outdoors), modifying their designs, and testing the modifications.
3. Be sure to encourage continued modification by monitoring students' activities and asking questions, making suggestions and using similar facilitation techniques.
4. Facilitate a group discussion in which students can share their designs and results. Be sure to focus students on the science principles and scientific process at work in their experiments.
5. Provide students with 3 or 4 different weights of paper.
6. Have students fold a traditional-style paper airplane from one piece of paper.
7. Give each student a paper clip to use as a rudder to improve the speed and height of the plane's flight.
8. Allow plenty of time for exploration.

9. Facilitate a discussion during which students develop generalizations about what factors helped and hindered flight effectiveness with questions like:
    - "What is the farthest that we could make a paper plane go? Why?"
    - "Why do some planes work better than others?"
    - "Which kind of paper is better than the others? Why?"
    - "Which designs work better than the others? Why?"

Subject integration

History. Conduct these activities as a part of a lesson concerning Leonardo DaVinci's development of the flying machine.

Extension activities

See the References listed on pp. 293-314 for related learning activities.

INVENTIONS

Learning objective

Students will develop a machine that will do something.

Prerequisite skills

Ideally, students should understand how simple machines (e.g., levers, pulleys, gears, inclined planes, wheels and axles) work. However, students can succeed at this activity without a background in simple machines.

Materials

It is best to provide students with a wide variety of "recycled" and "junk" materials for this activity. Use the following list for ideas and add your own materials. Balloons (several shapes)

- Beads
- Blocks
- Brad nails
- Buttons
- Cardboard
- Craft or popsicle sticks
- Dry spaghetti
- Egg cartons
- Empty thread spools
- Empty boxes (e.g., cereal)
- Empty film cans
- Feathers
- Fishing line
- Magnets
- Metal or plastic pipes
- Milk cartons
- Miniature marshmallows
- Modeling clay
- Mousetraps
- Old panty hose or nylons
- Packaging peanuts
- Paint stirrers
- Paper bags (several sizes)
- Paper clips
- Paper plates
- Paper towel and T.P. rolls
- Parts of old machines
- Plain paper
- Plastic bottles
- Plastic bag twist ties
- Plastic lids
- Potato slices

Rubber bands
Shoelaces
Small pieces of wood
Spice drops
Spring-type clothes pins
Straws
Thin metal coat hangers
Thumbtacks
Tin cans (filed)
Tinker Toys®
Toothpicks
Unsharpened pencils
Various sizes of washers
Yarn and string

Engagement activity

Younger students may need some preparation for thinking creatively in the exploration activity. Therefore, encourage creativity by having students invent new uses for common items (e.g., brick, coat, hanger, potato).

Exploration activity

1. Have students examine the materials available for machine parts.
2. Instruct them to work individually or in pairs to design and build a machine that **does** something. *(Hint: You can have students develop their own ideas or choose from the "Invention Options" that follows. Help them develop their own ideas by circulating, observing, and providing support for those who appear to be having a hard time coming up with ideas. Use questions such as: "What will your machine do?", "How could you combine things to make your machine work?", "How will it work— how will the parts interact?", and "What materials will be required to build it?".)*
3. Have students draw their machines. Then instruct them to describe their machines with words (e.g., What does it do? How does it function?).
4. Help students share their descriptions and drawings with a classmate/another team.

5. Tell them to name their machines (optional).
6. Instruct students to build their machines.
7. Once students have had ample construction time, have them demonstrate how their machines work. *(Hint: Some students may want to develop a TV commercial that describes their invention.)*

Invention options

Students may need some help with invention ideas. Thinking about what their machines would do is the best starting place. They can create machines that will perform one or more of the following functions:

- Pick up dirt from the floor
- Retrieve a paper clip from a high shelf
- Look around a corner
- Sort mixed beans and rice into separate piles
- Measure time
- Move a piece of paper across a room
- Lift an object without touching it
- Crack an egg
- Water a house plant
- Toss dice
- Mash potatoes
- Turn pages in a book
- Trap a fly
- Catch a raw egg (without breaking it!)

Explanation

Machines and mechanical systems in the workplace and the home are actually a combination of two or more simple machines. Students can gain an understanding of how machines and mechanical systems work by designing and building them. Understanding how systems work is critical to understanding how to solve problems related to those systems.

Be sure to facilitate discussions after students complete either the exploration or expansion activities to help them recognize learning, draw appropriate conclusions, and assimilate knowledge. Possible discussion questions include:

- "What did you learn about engineering from your efforts? What were your frustrations? Were you proud of your results?"
- "What energy transformations take place in your machine?"
- "Is your machine high in efficiency?"

Extension activities

- Have students work in pairs to build a maze that will take a marble from the top to the bottom of a shoe box in 30 seconds.
- Help students design and build a "contraption" that will move a marble from one place to another. It should have at least 3 moving parts.
- Create an exercise in which students design and build a moving vehicle that is powered by air only.
- Have students design, build, and demonstrate Rube Goldberg-style contraptions. *(Hint: You may want to share Rube Goldberg comics with students and have them examine and play with the Mousetrap game as engagement activities for this exercise. They could make their own Rube Goldberg cartoons, too.)*
- Divide students into pairs or small groups. Have teams design, build, and demonstrate a Rube Goldberg-type device that solves a problem with a minimum of 6 mechanical actions and reactions. Groups should brainstorm problem ideas (e.g. bursting a balloon, lighting a candle, turning on a radio, watering a plant, moving an object) and negotiate agreement among members for the group's choice.

BLACK BOXES

Learning objective

Students will develop process skills such as observation, prediction and inference from practicing logical thought processes in determining what is hidden in a box.

Materials

Boxes

Masking tape for sealing boxes

Hidden objects (e.g., metal washers or screws, straws, rubber balls, cotton balls, small beads,

coins—use your imagination)

Engagement activity

Talk with students about machines that have hidden "works" (e.g., pencil sharpener, disposable camera, clock). Help them guess how these machines operate. Instruct them to draw what they think is inside. Divide students into groups and let them disassemble some broken machines to analyze how they work. (You may wish to use the list of questions that teachers ask students as they analyze systems, pp. 19-22.)

Exploration activity

1. Provide pairs of students with a sealed box that contains several loose items.
2. Explain to students that you will answer questions with "yes" or "no" only.
3. Have them determine what's inside by making guesses and then testing them out (e.g., looking inside the box).

4. After students have explored several boxes, facilitate a discussion during which students can summarize what they learned. Be sure to help them recognize what skills they used properly when their guesses were correct, and how and when to use them consciously in the future. In addition, students should be given opportunities to ask questions, investigate topics about which they have questions, and find answers to their questions.

Explanation

Black box activities are structured so that students predict what is in the box. Such activities mirror the skills required (e.g., observation, inference, prediction) for making logical guesses about systems that are hidden from sight. Students will need these skills for job tasks such as troubleshooting, problem analysis and systems analysis.

Extension activities

- Have students complete the "Mysterious Pushrod Boxes" activity described in *Inventor's Workshop*. (See Appendix B, p. 293-314.) In this activity, students examine how pushrods move in a sealed box to determine, through prediction and experimentation, how the rods are connected.
- After completing the first extension activity, help students create their own pushrod boxes and exchange them so they can determine how one another's boxes are configured. *(Hint: Pushrod boxes can be constructed with dowels, paint stir sticks, or tagboard.)*

- Have students fix the rattle in The Rattle Box. Let students examine a black box that rattles when it is shaken. Instruct them to make and test hypotheses for fixing the rattle. Continue this process, giving students additional testing equipment that is comparable to advancements in technology and medicine (e.g., flashlight, magnet, probes, simulated xrays, and simulated ultrasound). Developed for grades 6-12, The Rattle Box kit can be ordered through William Sheridan & Associates, which is listed in Appendix B, pp. 313.
- Have students analyze broken toys and machines. Once they figure out how the broken items operate, have students suggest ways to fix them. This may involve the use of tools and measuring equipment. If appropriate, have students fix the items.

APPENDIX F

Selected Fourth-Grade Science Proficiency Outcomes

(Outcomes That are Relevant to Simple Machines, Electricity, Heat, and Liquids)

Strand I—Nature of Science. Refers to students' abilities and thinking habits in investigating science ideas. Outcomes in this strand overlap with traditional science units and with each other. Therefore, they should be reinforced throughout the science curriculum. That is, they should be taught in context—at every grade level.

1. *Create and/or use categories to organize a set of objects, organisms, or phenomena.*
2. *Select instruments, make observations, and/or organize observations of an event, object, or organism.*
3. *Identify and/or compare the mass, dimensions, and volume of familiar objects in standard and/or nonstandard units.*
4. *Use a simple key to distinguish between objects.*
5. *Analyze a series of events and/or simple daily or seasonal cycles and predict the next likely occurrence in the sequence.*
6. *Evaluate a simple procedure to carry out an exploration.*
7. *Identify and/or discuss the selection of resources and tools used for exploring scientific phenomena.*
8. *Evaluate observations and measurements made by other persons.*
9. *Demonstrate an understanding of safe use of materials and/or devices in science activities.*

Strand II—Physical Science. This strand is limited to physical principles of physics and chemistry that can be observed and explored without complicated instrumentation or theories.

10. *Explain the operation of a simple mechanical device.*
11. *Identify characteristics of a simple physical change.*
12. *Explain and/or predict the motion of objects and/or describe the effects of some objects on other objects.*

APPENDIX G

Matrices of Learning Activities, Proficiency Outcomes, and Process Skills

Two sets of matrices are included in Appendix G. The first set, "4th-Grade Science Proficiency Outcomes," illustrates the relevant proficiencies for each learning activity included in *Fun with Physics*. There are four proficiency matrices, one for each set of learning activities—simple machines, electricity, heat, and liquids. The second set, "Process Skills," outlines the process skills addressed by each activity. There are also four process skill matrices, one for each set of learning activities.

Page

- 4th-Grade Science Proficiency Outcomes for Learning Activities: Simple Machines, Electricity, Heat, Liquids 356
- Process Skills for Learning Activities: Simple Machines, Electricity, Heat, Liquids 360

4th-Grade Science Proficiency Outcomes* for Exploring Simple Machines Learning Activities

Outcomes →	1	2	3	4	5	6	7	8	9	10	11	12
Learning Activities ↓												
Scavenger Hunt	✓	✓						✓				
Wind 'Em Up		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Movin' Uphill	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓
Grand Prix		✓				✓	✓	✓	✓	✓	✓	✓
Trapping Bears		✓			✓	✓	✓	✓	✓	✓		✓
What's Going On In There?	✓	✓			✓	✓			✓	✓		
Wacky Inventions		✓			✓	✓						

* See p. 353 for a description of each proficiency outcome.

4th-Grade Science Proficiency Outcomes* for Exploring Electricity Learning Activities

Outcomes ➜	1	2	3	4	5	6	7	8	9	10	11	12
Learning Activities ↓												
Power or Not?	✓	✓		✓			✓		✓			
Go with the Flow			✓		✓		✓	✓			✓	✓
Light Bright		✓		✓			✓	✓	✓			✓
All Charged Up & Ready to Move	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Attractions	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Walter the Waltzing Worm	✓	✓			✓	✓		✓	✓		✓	✓

* See p. 353 for a description of each proficiency outcome.

4th-Grade Science Proficiency Outcomes* for Exploring Heat Learning Activities

Outcomes →	1	2	3	4	5	6	7	8	9	10	11	12
Learning Activities ↓												
Sun Power		✓	✓		✓		✓	✓	✓		✓	
Some Like It Hot	✓	✓	✓		✓	✓	✓	✓	✓		✓	
A Disappearing Act		✓	✓		✓	✓	✓	✓	✓		✓	
Dancing Quarters					✓	✓		✓	✓		✓	✓
Hot Foot—Cold Foot	✓	✓	✓			✓	✓				✓	✓
A Bunch of Hot Air		✓	✓					✓			✓	
Putting It On	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Keep It Cool	✓	✓		✓				✓			✓	

* See p. 353 for a description of each proficiency outcome.

4th-Grade Science Proficiency Outcomes* for Exploring Liquids Learning Activities

Outcomes →	1	2	3	4	5	6	7	8	9	10	11	12
Learning Activities ↓												
Ready, Set, Float	✓	✓	✓	✓			✓					
Wave Bottles		✓	✓			✓	✓	✓	✓		✓	✓
Goopy Goop	✓	✓						✓	✓		✓	
Traveling Marble		✓		✓				✓				✓
Busy Colors		✓	✓			✓	✓	✓	✓		✓	✓
Bubbles Bubbles Everywhere!	✓	✓	✓				✓		✓			
Squirt Gun Fun	✓	✓	✓		✓	✓		✓	✓			

* See p. 353 for a description of each proficiency outcome.

Process Skills for Exploring Simple Machines Learning Activities

Process Skills →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Learning Activities ↓															
Scavenger Hunt		✓	✓	✓							✓			✓	✓
Wind 'Em Up	✓		✓	✓		✓			✓	✓	✓	✓	✓	✓	✓
Movin' Uphill	✓		✓	✓		✓			✓	✓	✓	✓	✓	✓	✓
Grand Prix	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Trapping Bears	✓		✓	✓	✓	✓	✓	✓			✓		✓	✓	✓
What's Going On In There?	✓		✓	✓							✓	✓		✓	
Wacky Inventions	✓		✓			✓							✓	✓	

Process Skill Key

1 Building models
2 Categorizing or classifying
3 Communicating
4 Comparing
5 Controlling variables

6 Experimenting
7 Hypothesizing
8 Inferring
9 Interpreting data
10 Measuring

11 Observing
12 Ordering
13 Predicting
14 Recognizing relationships
15 Recording

Process Skills for Exploring Electricity Learning Activities

Process Skills →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Learning Activities ↓															
Power or Not?		✓	✓								✓				✓
Go with the Flow			✓	✓		✓		✓	✓		✓			✓	
Light Bright	✓		✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓
All Charged Up & Ready to Move	✓		✓	✓		✓			✓		✓		✓	✓	✓
Attractions	✓		✓	✓		✓			✓	✓	✓		✓	✓	✓
Walter the Waltzing Worm		✓	✓	✓		✓	✓	✓	✓		✓		✓	✓	✓

Process Skill Key

1 Building models
2 Categorizing or classifying
3 Communicating
4 Comparing
5 Controlling variables
6 Experimenting
7 Hypothesizing
8 Inferring
9 Interpreting data
10 Measuring
11 Observing
12 Ordering
13 Predicting
14 Recognizing relationships
15 Recording

Process Skills for Exploring Heat Learning Activities

Process Skills →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Learning Activities ↓															
Sun Power			✓	✓			✓	✓	✓	✓	✓		✓	✓	✓
Some Like It Hot			✓	✓		✓		✓	✓	✓	✓		✓	✓	✓
A Disappearing Act			✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓
Dancing Quarters			✓			✓	✓	✓			✓		✓	✓	✓
Hot Foot—Cold Foot		✓	✓	✓							✓	✓			✓
A Bunch of Hot Air			✓	✓	✓	✓	✓			✓	✓		✓	✓	✓
Putting It On	✓	✓	✓	✓		✓			✓	✓	✓		✓	✓	✓
Keep It Cool		✓	✓	✓		✓	✓		✓		✓	✓	✓	✓	✓

Process Skill Key

1 Building models
2 Categorizing or classifying
3 Communicating
4 Comparing
5 Controlling variables
6 Experimenting
7 Hypothesizing
8 Inferring
9 Interpreting data
10 Measuring
11 Observing
12 Ordering
13 Predicting
14 Recognizing relationships
15 Recording

Process Skills for Exploring Liquids Learning Activities

Process Skills →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Learning Activities ↓															
Ready, Set, Float		✓	✓			✓					✓		✓		✓
Wave Bottles	✓		✓	✓		✓				✓	✓		✓		✓
Goopy Goop		✓	✓	✓		✓				✓	✓	✓	✓		✓
Traveling Marble			✓	✓	✓	✓	✓			✓	✓		✓		✓
Busy Colors			✓	✓		✓					✓		✓		✓
Bubbles Bubbles Everywhere!		✓	✓	✓							✓		✓		✓
Squirt Gun Fun		✓	✓	✓		✓				✓	✓		✓		✓

Process Skill Key

1 Building models
2 Categorizing or classifying
3 Communicating
4 Comparing
5 Controlling variables
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FUN with PHYSICS

Real-Life Problem Solving for Grades K-3

Teachers and students are talking about Fun with Physics:

"I have taught this unit at least three other times BUT this time it was far superior because of the creative, hands-on activities from your book."

Pilot Teacher

"[The activities] were fun to do, and it made learning fun. I especially like taking machines apart. There's a lot of things in a telephone that I didn't know about."

Pilot Student

"Those things I picked were very fun! But they were also very interesting. I learned a lot with them...enjoying myself at the same time. I really hope we do more activities like this."

Pilot Student

In-Service Training

The Vocational Instructional Materials Laboratory (VIML) at The Ohio State University provides coaching and training that will prepare teachers and trainers to effectively use the Fun with Physics books, and other VIML publications. Workshops in problem solving with physics andmath for grades 9-12 and adults working in industry are also available. For further information about these services, contact the VIML at 800/848-4815 or